

## IMPORTANT POINTS I ALWAYS FORGET

- When working with **nanostrip** or HF must work in pairs and must work in suits.
- 1 unit in Autocad =  $1 \mu\text{m}$
- Remember to ground when working with JJ!
- HF is used to clean the substrate from organics;
- Clean thickness crystal in potassium hydroxide (pellets) with water once they have had too much material deposited on them.;
- The Olympus microscope flips the orientation.

## MAGNETIC FIELD - CURRENT CONVERSION DURING EXPERIMENT

The proportionality constant converting mA to Gauss:

$$\text{Cell}_T = 1.65 \text{ [G/mA]}$$

$$\text{Cell}_A = 1.56 \text{ [G/mA]}$$

Therefore to map flux to current:

$$\Phi = I_{mA} \times \text{Cell}_{T/A} \times \text{Area}$$

or in SI units:

$$n_\Phi = \frac{\Phi}{\Phi_0} = I_{mA} \times \text{Cell}_{T/A} \times 10^{-4} \times \text{Area} \mu\text{m}^2 \times 10^{-12} \times \frac{1}{2.067 \times 10^{-15}}$$

$$= \frac{I_{mA} \times \text{Cell}_{T/A} \times \text{Area} \mu\text{m}^2}{20.67}$$

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CHAPTER 1

# RHUL THE CHOOK-CHOOK

Valve 2 - its the equilibrator for V1 - you need the same pressure on either side of V1, and you use V2 to do this. Then, the can open V1.

The cooling system is composed of two parts

- The pulse tube that fires in helium and expands it - it uses the big compressor in the shed.
- The circulating cycle of He3 that is pumped out of He4. This is the big contour on the right of the big screen. P3 monitors the pressure before the capillary constriction that this mixture is funneled through.

## 1.1 Pumping

System needs to be pumped to avoid formation of ice when it is cooled.

1. Can load the two blueforce programs on the desktop or mash buttons on the big panel;
2. First stop venting by closing valves 14, 16, 19;
3. Close the cases, with the stitch facing the far wall of the lab;
4. Check the pressure is > 40Bar on the cylinder in the corner and 80psi on the output since this is used to operate the valves;
5. Refill the trap with nitrogen so its full. The trap will absorb gases that are not Helium - they liquify? Eventually we need to replenish it;
6. Turn on the Scroll Pump 2 → V21, V16, V14 for rough pumping. **Wait until ‘‘P6’’ reads 1mbar.**
7. Pumping contaminated mixture in condenser line (around V4, V5) and still line (V3):  
**ensure that scroll is only pumping through V21 and that there is no mixture in the DR loop**  
→ open v17, v3, V2 (to equalise pressure across the big valve) to pump the still side and V5 to pump the condenser line side;

8. Start pumping the trap → **close V14, V16** → open V17 and V7 (V21 will still be open) → wait 15–30 minutes.

When we circulate the helium in the cycle, we pass it through the Nitrogen trap (the tank). Nitrogen, and oxygen will be condensed in this trap, so only volatile things like hydrogen and out helium will pass through. This means that at the capillaries we don't have oxygen/nitrogen plugs forming.

At room temperature we must pump the trap to remove the gases that we adsorbed onto the carbon mesh inside the trap.

**Position the trap in the the can! DO NOT TAKE OUT EVEN WHEN TOPPING UP!**

9. **Close V17 and V7.** Pump the can again by opening V16 → V14. Wait until “P6” = 1mbar;
10. **Activate the turbo pump:** Close V14, V16, V21 → Open V23 → turn on Turbo2;
11. Go outside and press start/stop on the left-most bottom box → Open the dump valve by turning the black knob (which you cannot see) clockwise;
12. Open V22, V16, V14;
13. Turn on P1 on via the MaxiGauge board;
14. Dip the trap into the nitrogen tank;
15. After getting  $3 \times 10^{-3}$  mBar → programming → load → installation package\control scripts \with extra turbo \LD\_auto\_cooldown\_w1N2\_extra\_turbo\_V1\_21\_V23\_open → run;
16. **Good parameters are 17 °C input water, 33 °C output water, 35 °C oil colour.** If required, go to pumps in back of room, and select constant pressure.
17. In the morning the can should have been pumped already (V14-16-21 closed). We need to close the turbo and scroll pump → Go outside and switch turbo off → close turbo on computer panel → close backing V23 → close “scroll pump”

## 1.2 Mixing chamber circulation

So, the first part of the cooling process is done with the pulse tube, cooling to 5K, after which the He3 is pumped through He4 in the mixing chamber. This is driven on the right-hand-side of the panel, and it's the second turbo that causes this circulation.

In order for there to be enough He3 circulation, **we actually need to heat the still stage so that the mixing chamber cools quicker.**

1. Thus, once still temperature (Ch5) reaches 600 mK (and flow rate lowers to 30 mmol/s) → set ‘‘Heat Analog2/Still’’ to 10 mW;
2. **Make sure flow rate is 60 mmol/s;**
3. **Make sure still temperature is approximately 850 mK.**

This will ensure that the mixing chamber gets enough He3 circulation to cool to the base temperature of 13 mK.

### 1.3 Shutting down

1. ‘‘Maxigauge’’ → ‘‘sensor P1’’ → ‘‘off’’ to shut down sensors during warmup;
2. In the program load ‘‘warmup’’ recipe → run;
3. When ‘‘MaxiGauge’’ → ‘‘Channel 5’’ reads 800 mBar get readt;
4. Proceeding clockwise, close all of the values in the circulation cycle V7 → V4 → V1 → V3 → V10 → Scroll → V13;
5. Remove trap from the can. **Close the can with the lid;**
6. Turn off the BlueFors little box;
7. Go outside and close the dump valve by turning black handle (which you can’t see) clockwise (from its perspective). All of the helium will be trapped in the dump, so that it can be reused in the next cycle;
8. After a few days, you can vent. ‘‘V19’’ → ‘‘V16’’ → ‘‘V14’’.

### 1.4 Pumping the trap

The trap, which distills all kinds of gasses that leak into the Helium system, needs to be pumped before the next cooldown:

1. Make sure the trap is out of the canister;
2. ‘‘V2 Scroll’’ → V21 → V17 → V7. **Wait for 1 hour!**
3. V7 → V17 → V21 → ‘‘V2 Scroll’’.

## 1.5 Heating up the cell

If we want to increase the temperature in the cell, we need to apply the heater in the blue Force program. Standard: Control channel = 6, heater = current, heater resistance = 120, pause time = 60, proportional = 10, integral = 2, derivative = 0.

1. “Maxigauge” → turn off 1, 2,5 → the temperature readings on the box should read “disable”;
2. “Heater setup” → “control mode” → “closed”;
3. Set the “setpoint” temperature you want;
4. change the “heater range” current 1-10mA depending on how fast you are hating You may need to increase the “Heater Limit”, as it acts as the safety stopper (to not overshoot the current);
5. “Write settings”;
6. Monitor temperature and make sure not to overshoot.
7. “Heater setup” → “control mode” → “off” → “Setup” → turn on 1, 2,5

## 1.6 Computer monitoring BlueForce

1. To connect to the BlueForce logs, log 192.168.0.4 with password resonator1
2. To access monitor connect TightVNC viewer with password qubit2

CHAPTER 2

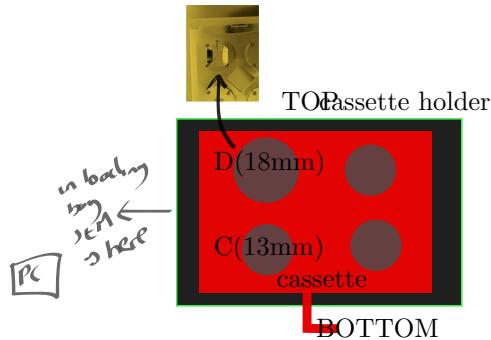
# EBL RHUL JEOL 8100x

Password: Jeoleb

Lifehack - to close lines run the command `pedit`.

## 2.1 Loading and unloading

- `jbxwriter` → Stage control → Fixed Position = ORG → Move. The Current Position should be close to  $X \approx Y \approx 100\mu$ ;
- Turn the black and red lock open;
- Press flashing green LOAD/UNLOAD button and hold for 3 seconds. You will hear valve opening;
- Grab cassette - it should naturally tip to safe position; **Do not touch corners** - they are used for height measurements. If dirty clean with IPA;
- Load in the chip or wafer, performing alignment as in Subsec. 2.2;
- Load cassette as below:



- Load, unload → wait 3 seconds;
- Check Manual Loader Viewer in `jbxwriter` → Blue means cassette is loaded;
- It is recommended to wait one hour after loading for the temperature to stabilise. The temperature fluctuations can be checked following steps outlined in sec. 2.4. During the exposure the temperature

should not change more than 0.05 degrees Celsius. If the exposure is short it might not be necessary to wait a full hour.

## 2.2 Finding the markers before loading

To align the chip in the JEOL, you need to tell `jbxwriter` the location of the PQRS and first chip in the coordinates of the cassette. This is done on the microscope next to the door.

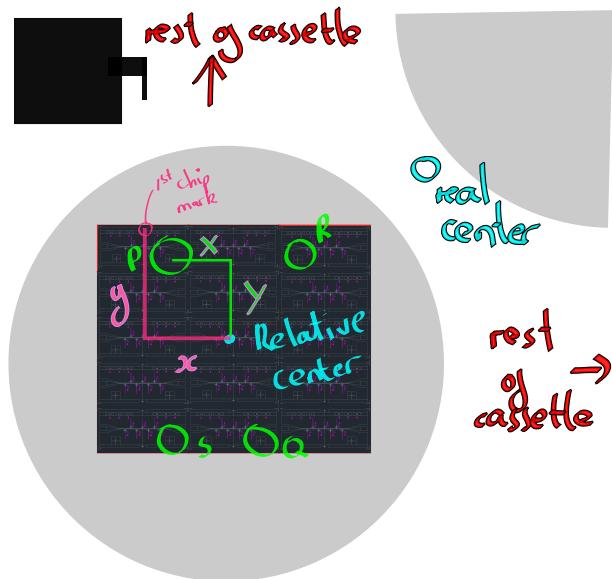


Figure 1: To align the chip, both you need to defined the PQRS global markers and chip markers.

Measurements are made relative to the center of the window you have chosen

- Select cassette name e.g. 2inch multi E;
- Select window e.g. 2E → The window should turn red in the program;
- Locate PQRS and the first chip marker and take down the positions → make sure you know the real positions as well

Marker	Design Location	Measured Location
P	-4000, 5000	-4333, 5050
Q	+4000, -5000	3666, -4950
Chip	+100 relative to P	-4333, 5200

## 2.3 GDS Conversion

If file is in gds-format, you first need to convert it to v30 following the steps below. Note that each layer has to be imported separately. Know your layers!

- Open “jbxconv” on main console (DELL computer).
- Choose your file: File → Open.
- Choose **Structure and Layer**.
- Choose “Size parameters”.
- Command → Start Conversion → OK.

Parameter	Meaning	Where to enter	Example
Cassette name	The big metal hunk being used	Marker Location, jobmaker, Material Correction	2 inch
Window name	Window chosen	Marker Location, jobmaker, Material Correction	2C
PQRS by design	Where they should be according to design	jobmaker	(4000,5000)
PQRS real	Where JEOL will locate them	Marker Location, Material Correction	(4334, 6000)
Condition file	Aperture and Current used	jobmaker, Material Correction	2nA_60um

## 2.4 Checking temperature fluctuations

- Terminal → ebanalyze → trend;
- Select start and end date time → Press search;
- Click on file, it will turn black;
- Press “check”.
- To see graph select “MONTMPS” for temperature, “MONVACS” for vacuum, “MONACCS” for accelerating voltage.

## 2.5 Condition file

This sets the current and aperture for the JEOL.

- jbwriter → Condition → Condition File Loading → Calibration Condition File Select;
- For each option, available Condition files will appear in a table. Choose the appropriate one. If the desired condition file does not exist, ask Dr. Shaikhaidarov to create it.
- Apply;
- Tick the “Restore” and “DEMAG” option → Press **check** to check that the condition file was created recently;
- Change aperture: Open the “Main Console Access”-door. Pull and turn cylinder handle to the appropriate aperture
- Press **execute** and the settings from the condition file will be applied;

High throughput High resolution	Current 10-100nA 200pA	Aperture Size 300 µm - 8 60 µm	Lens 4th Lens 5th Lens (only for 200pA)
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## 2.6 Alignment after aperture is changed

- In the top right of the console **Choose BE as Fixed Position**. We will perform initial calibration on this marker.
- Press **Move** → press **SEM** to activate SEM;
- For faster scan tick **Rapid** and press **Apply**;
- Adjust **Brightness** and **Contrast**. It is a good strategy to put the contrast to maximum, and adjust the Brightness;
- Adjust magnification;
- Initial calibration should be done with back-scattered electrons (BE);

The outcome of this should be a cross like so:

- In the **Alignment Tab** Press **WOBB** → Press on the lens you are using (it will be lens 4);

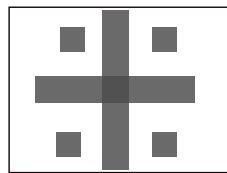


Figure 2: The goal is to make the cross stop pulsating

- Eliminate wobbling by turning dials on the rod with the apertures stick - start with one to eliminate diagonal (the closest dial) and then the other to eliminate other diagonal; **The image should pulsate but not move laterally.**
- Turn off wobbler by clicking **Wobb**, and wait for DEMAG to complete → SEM OFF.

## 2.7 Calibration

### 2.7.1 Current calibration

- In the **Curr. Adjust.tab**, tick **Beam Current Measurement** **Do no need to do the ticking and sections below most of the time.**
- Press **Execute** and a current will be measured (check logs);
- If all is good, proceed to repeating the wobbling steps described in Sec. 2.6.
- Otherwise, follow these steps in order.

#### Option 1: Shifting aperture.

- Press **Align** → a circle with crosshairs should appear on screen. This is the aperture and we want it to be centered.
- Press the **[2 al. shift]** on the grey console (above keyboard, below screen). Use **X** and **Y** knobs below to position aperture in the middle;
- **Align off.**
- Check current again and check wobbling.

#### Option 2: Tilting to improve beam current

- Move to **FC** (Faraday Cup) in the top right corner of the application;
- Click **SPOT**;
- Click **2 al. tilt** → Toggle x/y to maximise current;

- Check current again and check wobbling.

### Option 3: Demaging

- Press **2/3** on the grey console → Toggle focus wheel to increase/decrease current;
- Once current is obtained press **DEMAG** → Press **2nd**;
- When **2nd** is off, press **3rd**.
- When **3rd** is off, press **DEMAG** (it will turn off);
- Use the focus knob to change current again;
- Press **4th** → **SPOT** off.

#### 2.7.2 Focusing

For large 100nA current, you must focus yourself, because the machine does a bad job.

- Click **SEM** on and move to marker **SEM SP**;
- Set **x3000 magnification** and **do not use rapid scan**;
- Pull out the small table and adjust focus using the grey controller:
  - Use 4th lens;
  - Click **FINE** for finer movements;
  - Turn the **LENS/DF** dial.
- Press the **Stig** button and remove astigmatism.
- **Even better to do it on SEM SP**
- **To not perform automatic focusing after this, simply skip this tab.**

If not using 100na, automatic focusing will work.

- Tick **Static Focus Correction** in the Focusing-tab.
- Execute → Save

### 2.7.3 Standard mark detection calibration

- Tick AE and BE Mark Detection in the **STD. Mark Detection**.
- Press **Execute**
- If marks were found, press **Save** in the **AE panel** and **BE panel**;
- If not:
  - Increase the Scan width to  $40 \mu\text{m}$  and repeat mark detection;
  - If marks are now found, press **Save**;
  - Decrease the to  $4\mu\text{m}$  → Press **Apply** → Press **Execute** → Press **Save**;
  - Can also increase **raster** - this will increase number of averages
  - In the Wave-tab change Gain and Offset;
  - Press Applies to Calibration → All select → Apply;
  - Stop Wave and try executing again;
  - Can click on **Wave** tab and button - here you can change the gain to for better detection.

From Rais file, if detection still fails: Turn on [SEM].. At the BE conditio press [make current posit on default]. [save]. OK. AE: check mark condition to find wha corner to align to. (4,4)-bottom left, (4,-4)-top left, -4)-top right, (-4,4)-b ttom right Position corresponding co ner in the center of the screen. Press [Regi OK. At the AE conditio press [make current pos tion default]. Ok. Execute dete tion of both AE a d BE marks. .

If detection still fails, time to find markers manually:

#### Finding BE manually

- Turn on **SEM**;
- Move to **BE** and use arrows to move marker to middle of the screen;
- Press **Register** (in the fixed position submenu);
- In the **BE Tab** update the BE coordinates by clicking **Make current Position default**;
- Press **Save**.

### Finding AE Manually

- Check the mark condition, to find the corner to align it to:
  - (4, 4): Bottom left;
  - (4, -4): Top left;
  - (4, -4): Top right;
  - (-4, -4): Bottom right;
- Turn on **SEM** and move crosshairs, so that the relevant corner is in the center of the screen;
- Press **Register** (in the fixed position submenu);
- In the **AE Tab** update the AE coordinates by clicking **Make current Position default**;

After manually finding AE and BE **rerun automatic detection**. Remember to save both AE and BE!

#### 2.7.4 Deflection correction

- Tick all options (Main DEF., Sub DEF., Dist. corr.) in the **DEF CORR** tab;
- Execute → Save
- You may want to check that the calculations values for the convergence judgment X,Y are below 4 nm (6 nm) for lens 5 (4) in the “Log”.

#### 2.7.5 Material Correction (aligning the sample)

For layers after the first one, aligning higher layers will require execution of this step.

- The coordinates of the markers are measured outside the SEM (in absolute coordinates) relative to the **whole cassette**;
- The real coordinates of the markers are written in Stage 2.8.

The easiest way to deal with P and Q coordinates is to set  $P=(0,0)$  and set Q to whatever it's offset is relative to it.

- Tick **Global Mark Detection**;

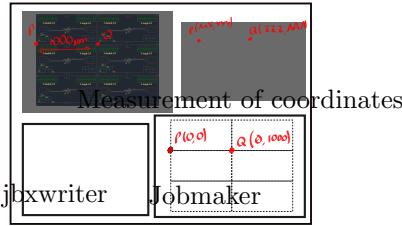


Figure 3: Location of P and Q coordinates

- Select the chip holder and window;
- Enter the P and Q mark coordinates that were taken **outside the SEM**. If it happens that this was not done, you will have to unload.
- In the **Global Mark** menu click **RG Detect Condition** → in **Scan Type** enter width of mark;
- Repeat for **Q Rough Scan**, **P Fine Scane**, **Q Fine scan**;
- Execute → move crosshairs to center of mark → Press **Save**;

Of course the marker will be at an offset to where you expected it to be. Find this offset in the log file and make a note of it.

This offset will be added to Stage 2.8 when we prepare the file by clicking **Read offset**.

#### 2.7.6 End of calibration

Update → Save and exposure is ready to go.

#### 2.8 JobMaker

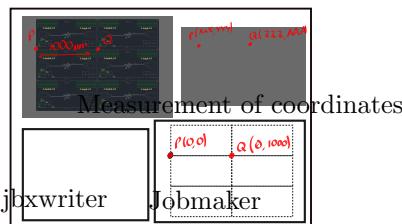


Figure 4: Location of P and Q coordinates

- Select Cassette name and choose window.

- Press Job Property and a window “Job 1 Property” will pop up.
- In that window under the Calibration heading
  - Select EOS Mode.
  - Choose your Condition File.
  - Choose your Calib. Menu, for example DIRE01.
- Under the Exposure Condition heading
  - Choose Scan Step
  - Enter Beam Current
  - Choose OL Aperture
  - Choose dose (the resist does not matter)
- Under the Alignment heading
  - Tick Global Mark Detection
  - Choose Mode “Semi Auto”
  - Copy your P and Q mark coordinates from the Log file (You have taken a note after doing the Global Mark Detection). item Tick size
  - Enter width and length of your marks item Tick Height Detection, change Offset to the values found in the Log file (from when Global Mark Detection was done)
  - Tick Chip Mark Detection
  - Choose Type
  - Choose Mode
  - Tick Height Detection
- Press OK. The window will close. P and Q marks appear on the wafer in the “EB Job Maker”.
- Open “ptnview” on the Desktop to check your pattern.
- If satisfied, return to “EB Job Maker”.
- Below Chip List, below Chip a, click on “...”-button. A window pops up.
  - Choose your file and press Open.
- Press on “a”-button and drop it on the wafer.

- Right click on it and select “Chip property”.
  - Choose Center Position
  - Choose “Subfield Sorting” (Direction of exposure)
  - Press “Shot Rank Table...” next to Shot Rank and a window will pop up. Here you need to set the doses, enter Modulation in %. Press Close.
  - Enter your chip mark coordinates. tem Choose shape of your chip mark.
  - Enter your chip mark size.
  - Press OK.
- To create an array, right click on your pattern and select “Array”. A window pops up.
  - Choose your array size (Number)
  - Choose your chip to chip distance (Pitch)
  - You may want to tick Grouping, especially if you are planning to create another array of the array (Nesting).
  - Press Ok
- You may create another array if you wish.
- Save File.
- Compile (triangle icon) and press OK.

Return to “jbx writer”

- Before exposure click read offset to transfer alignment information from jbwriter to this design file;
- Press “Exposure” button.
- Press open and select your Magazine File, the file you have just compiled.
- Press “Start Exposure”-button, press OK.
- You can monitor, the progress of exposure: Yellow (writing), Blue (completed)

## 2.9 For JEOL engineers and advanced users only

In the Focusing tab

- Only tick Static Focus Correction

- Choose SF/SSX/SSY;
- Press Execute → Save;

In the “DEF. Corr.”-tab

- Tick Main DEF, Sub DEF, and Dist. Corr.;
- Allowable gain error should be 4nm;
- Distortion error should be 6nm (4nm) for lens 4 (5);
- Execute → OK → Save;

### 2.9.1 Checking how marks are detected (this does not affect the calibration file)

In the Material Corr.-tab → use semi-automatic mode. First Global Marks:

- Have only Global Mark Detection ticked
- In the Global Mark tab have only Q point ticked;
- Enter the position of your Q mark of your specific wafer;
- Execute → Ok;
- If it fails, untick Rapid, increase scan width to maximum and press Apply;
- When you found the markers, tick Grid under the SEM-tab and press apply, position marker to the centre, and press Continue and Save;
- In the Log check the offset and type it into the set field in the Global Mark tab

Here take note of the P, Q and offset values. They will be used below.

Then Chip Marks:

- Have only Chip Mark Detection ticked;
- Choose a mode;
  - 1 for one mark and offset, but no rotation;
  - 4 for four marks and rotation, measures position and height;
  - V1 and V4 for auto focus
- Execute → Update → Save

## 2.10 Creating pattern

Claibrating the EBL is all good. We also need to prepare the pattern that it ill expo e. Do this n verb— B Job Mak r—. The main goals ar : ginenum rate iem efine th coordinates of the global markers:

- Job property;
- Select Window position on the sample holder you are using (A, B, C ,D);
- Select the window size. Big wafers are 3" and a 2x2 chip fits a 2";
- Define the coordinates of the global markers P and Q using the coordinate and offset values you foun during ca ibration. Yes - just copy them.
- Tic other pr such as current, calibration file etc.
- Select the .v30 pattern to expose → Right click to make an array of them;
- Right click on the pattern → Define the position of the chip mark for the first pa tern.  
If you want to offset the patte n to be in betwen the chi s apply (-402,-46 set);
- Save and load it up for exposure.

For movement, make sure that cassette in the top right corner is the one you chose.

CHAPTER 3

# RHUL FOCUSED ION BEAM

- 79.3K gun temperature;
- 58.7 K Dewar Temperature.

## 3.1 Unloading

- Make sure gas is off on the **Vacuum Dashboard**;
- Click the **Loading** button on the top bar;
- Click **Exchange** and wait for stand to move and **wait for green light**;
- Pull the sample out;
- Click **Store** which will close the door. **wait for green light**;
- Click **Vent** and wait for lock to open;
- Screw in the bar and pull out;

## 3.2 Loading

- Load the sample;
- Click **Store** which will pump the chamber;
- Click **Transfer** and push the stage in;
- Click **Store** again to pump loading chamber again;
- **Click Resume** and stage will move;
- Right click and **Helium On**

Before leaving, right click and Helium Off.

### 3.3 Checking trimer

- Click **SFIM/Normal** button and right click to turn on crosshairs. Check that one of atoms is in the center.

**Good parameters:**

- 1024x1024;
- 16 lines averaging

# CHAPTER 4 EBL RHUL FILE PREPARATION (BEAMER)

For making the pattern we can either:

- Create a full wafer design in autocad/beamer → supply the P, Q coordinates → perform a full exposure;
- Design individual pattern in autocad/beamer → supply P, Q, chip marks, arrays at JEOL (see Subsec. 2.10) → perform exposure.

When creating a full wafer pattern, we will use 1/4 of a 3" wafer **which we load into a 2" window**.

## 4.1 Autocad

To make patterns for the lithographer (optical and electron beam) the designs need to be made in Autocad. Draw whatever you want, but follow these rules:

- There must be an object in the zero layer;
- All shapes **must** be polylines. They must be joined up in a single line, or they won't work;
- Units are in microns;
- **Place small markers in the corners of the pattern so that centering is correct;**
- Once design is finished, **select all** → Purge → All → type "none\*" → Yes to all;
- Save as **Autocad DXF** to use it in beamer.

Important is the **extent** of the pattern. This is the dimensions that the pattern will be overlayed on e.g.  $100 \times 100 \mu\text{m}$  which we can enlarge, scale etc.

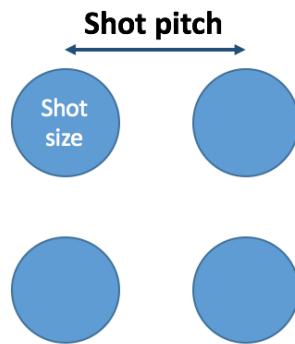
The base dose, relative to which all the dosing is done, will need to be experimentally found by doing test patterns on JEOL. Only then do the relative doses that the program makes will mean something.

## 4.2 General information

- Sending is done via FTP with **FileZilla**;
- Internally, beamer uses its own file format during its processing;
- Double click in bottom right symbol to view pattern. **Right mouse click** to do measurements. **Tick** and **clear** to retain commands during movement and zooming in;
- **Shot settings** button to see dots that JEOL will fire;
- **Layout B(oundary)box** button to show extent of pattern;
- **Colour by cell** to highlight colours in design;
- “Doses → Get Limits from Layout” to recalibrate the dose scale;

## 4.3 How exposure is being done

- JEOL switches between different fields, ‘stitching’ them together;
- JEOL starts in the upper left. Then it fills either *X* or *Y* direction trapezoids;
- **Shot size** = size of the circular shots that are going to be taken by the Gaussian beam. Typical is 2-3 nm, defined by the regime of JEOL;
- **Shot pitch** = beam step size as it moves from position to position;
- Designs snap onto JEOL grid, which could distort shapes.
- Backscattering  $35 \mu\text{m}$  for 100 keV and silicon;



## BEAMER TIME!

Beamer works in relative doses:

- 1 = no dose modulation;
- 0.8 = -20% of the dose;
- 1.2 = + 20% of the dose;

**The final dose depends on your shape, voltage, and the shot pitch**

To use variables in a for loop, declare them in the transform function (for example) instead of a number

*Rotate : %VARIABLE – NAME%*

and then increment them in the **loop** function.

### 4.4 Import

- Eats dwg → converted to internal file format;
- Convert colour to datatype to import layers by colour I do not use;
- The pattern is centered relative to the most extreme elements;

### 4.5 Actions

- Edit to allow change of design. **Run it standalone to create empty design;**

- **Mapping** change layer names to new ones (or into other layers);
- **Heal** removes overlaps - **merges into 1 layer**;
- **Merge** collect different layers;
- **Transform** to position about a chosen origin e.g. set “center” to 0,0. The pattern is done in order of appearance;
- **Grid** to put the design on a grid with new dimensions;
- **P-XOR** Delete odd number of overlays - **can be used to check difference between original and processed pattern**;
- **Loop** to repeat the operations. Merge results and “heal” to remove overlap;
- **FDA** modulate DOSE by layer;
- **Bias** is used to trim based on edges. Can be used to remove thin structures;
- **PEC** is standard proximity correction;
- **Ebeam simulation** is to see how the beam will write;
- **Visual Job** is a standalone block which we run independently. It creates a text file that specifies how the generate the arrays, maybe some scaling of the dose;
- **Split tool** to branch out lines;

**To draw line**

draw it → “export→ advanced” and choose **reserved line class**

- **Fracture** how the design is broken up. This is passed onto proximity correction (which subfractures the fractures)
- **Fracture** ⇒ **Advanced** → (**see below** Combine floating (fields are freely positioned) and fixed (fields are in a grid) and apply to different layers. Select all layers with \*);

## 4.6 Export

1. **Comma separated list** to choose layers to extract.
2. **Machine type** JBX-81000FS;

3. File type is .v30 (changes resolution and field size automatically)

- 3 - 100kV high Throughput maximum field size is 1mm×1mm;
- 6 - 100kV high resolution maximum field size is 100μm×100μm;

4. Shot settings

**finely spaced shots ≡ small doses on each shot.**

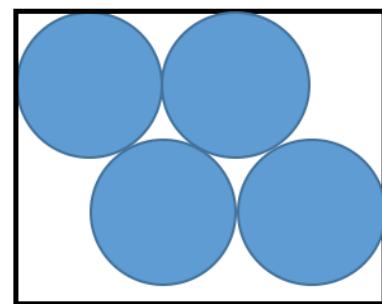
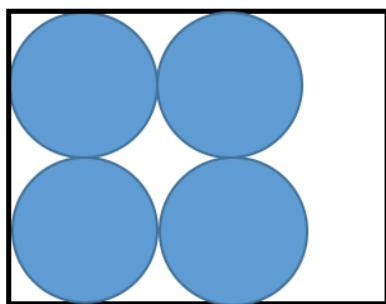
- Pattern unit (resolution) (depends on the mode, 3 or 6, **fixed by JEOL**). Essentially it is the resolution of the grid on which the shots are made
- Shot pitch (step size) is how much to separate the shots on this grid;

**Make sure you keep the same shot pitch in the JEOL machine! JEOL should prevent incorrect pitches.**

5. Field settings (JEOL moves stage to expose each field)

- Size of each field e.g. 1 mm ×1 mm is **fixed by JEOL** - below we change the data within the 1 mm fields, putting and taking away structures, overlapping and other shit;
- “Advanced → fixed” to position fields like a grid;
- “Advanced → floating field” to look for large blocks of items and center the fields on them;
- “Advanced → manual → view layout” to define your own field. **Selecting when floating** “Shift → draw box → double click”. **Make sure box is smaller than the main field**;
- “Traversal path” to see how exposure will jump between the fields;
- “Center to field” to make sure that important elements are in the field center.

6. Shot pitch factoring is where you tell the shots to be perfect on the edges, and overlap in the middle of the structure where it is not important;



7. Feature sorting in field how to save the order of elements inside the fields;

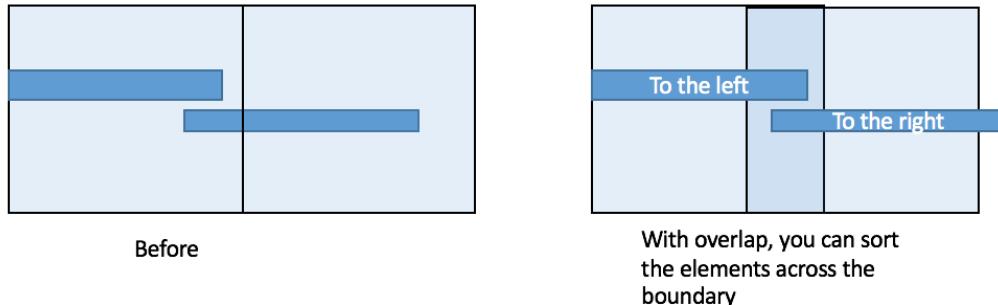
Feature sorting in field →

- By geometry to fill objects without jumping or another option;
- Left to right;
- By layer;
- Writing regions fills in region by region, who size you set.

#### 4.6.1 Multipass Tab

This is where you say for the beam to pass multiple times across the same areas to fix stitching problems

1. Field overlap, so that structures on the edges of two fields are not directly cut along the field lines, but sorted into the left and right sectors;



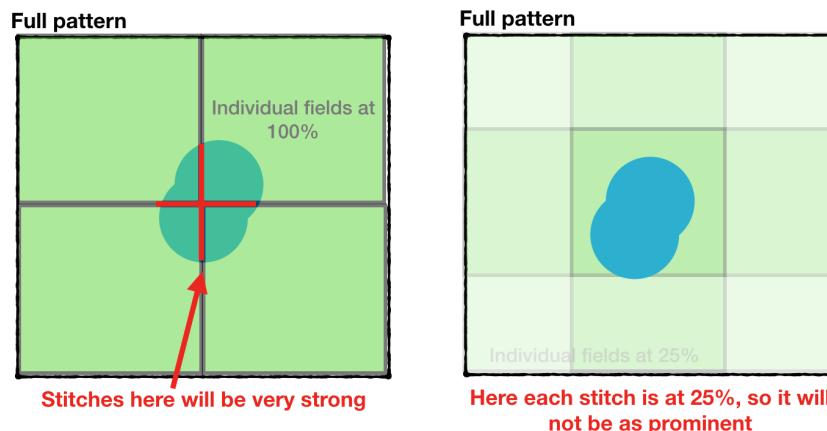
2. Multipass shifting and lowering dose is when a pattern broken up in such a way that the pattern is exposed 4 times, and given 1/4 of the dose each time. Stitches between fields are smeared out (as they are 1/4 intensity instead of full dose).

- Select number of passes and the overlap in terms of the mainfield dimensions. 0.5 is a good value.
- Remember the size of the subfield (sub part of the mainfield) should not be a factor of the mainfield size, or periodicity will appear at integer multiples.

#### 4.6.2 Improve field movement

For improved movement of microscope do the following:

1. Get pattern and bias it to grow a rectangle around it;



2. **Merge** to the original pattern - now you have a rectangle layer positioned on top of your pattern.
3. In export, select **region-layer** to choose the layers that will specify the centers of the respective fields.  
The machine will move to those rectangles, and look for exposure patterns there.

## 4.7 Increasing speed

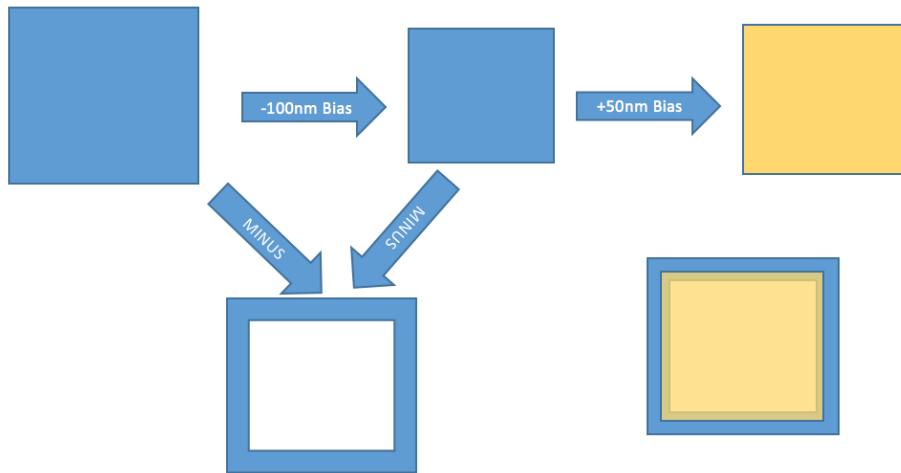
To increase speed, we need to draw the outline accurately, and do the filling at a larger current. Thus we need an outline and a fill design:

- **Bias** function will take your pattern and trim (e.g. 100 nm) from all edges;
- **MINUS** this pattern from the original → you get an outline of the original pattern;
- Then take another **bias** and add (e.g. 50 nm) to the first bias to create overlap between the cut out bias pattern (outline) and the middle pattern.

## 4.8 Proximity correction

Uses **Tracer** which we do not have

- **Long range correction is always being done!** Pixel based approach. It measure the local density, in the range of  $\beta$  and performs a correction based on this extra exposed dose;
- **Archive** to select
  1. Substrate e.g. Silicon+200nm PMMA;
  2. Z-position to set the position where the correction should be the best (could be top or bottom of resist). **0 for top of resist**



- ‘‘Accuracy’’ should be 1%.
- Tick `Include Short Range Correction` for small structures  $\sim 30$  nm, where the size of the onset beam can affect neighboring patterns. Off by default;
- `Effective short-range dose`;
- `Maximum number of dose classes` is the number of different doses. Accuracy sets the accuracy that are given to the dose classes. Too much accuracy fractures the design to assign these different doses, so **do not overdo it**;
- `Minimum dose` exists so that beam does not jump too fast (low dose, means beam can move across this area very fast);

Isodose grid defined the fidelity of the grid to be used → make sure that the Shot Pitch is larger than the grid so that you don't have 10 nm fractures, which you fill with 6 nm shot steps

- `Minimum figure size` sets the finest fracture that can be made.
- “Examples” → `TenDoses_100um_200um.fbd` that allows to expose a set of test patterns, which can be used to calibrate your own material (for future proximity correction values).

## 4.9 Visual-Job - prepare for exposure

To open, click on the icon in the toolbar in BEAMER (multiple dose tables created) or use the **CHIP PLACE COMMAND** (single dose table created)

1. Set the marks;
2. Create job name - **must be capital letters**;
3. **Shot pitch**;
4. **Array**
  - (a) Set the extent of the pattern slightly larger;
  - (b) Center the pattern;
  - (c) **Array dose** (start + end e.g. 0.8 to 1.2, linear) - separate .jdi files are created;
  - (d) Open “Place data in the side menu bar”;
  - (e) **Pattern Data** to set the marker.
  - (f) “Assign” to put the marker on the pattern.

## 4.10 Compiling on RedHat

- v30 files are created in `beamerv` and contain the **geometry** of the pattern;
- jdi files are created in `beamerv` and contain the **doses** for the pattern;
- jdf files are created in `Jod Editor` and create **arrays** of v30 patterns and **assign doses** to them.

1. Create an jeol exposure program in “`Jod Editor`” → “`File → Save As`” → save this project as a folder;
2. Copy the “`.jdi`” files into this folder;
3. Open “`terminal`” and run the command

```
./jeolrhul
```

4. Navigate to the jeol exposure program folder created using `cd` e.g.

```
cd ilya/2018files/transmonnpc
```

5. Run a script to apply a modulation of +0% … +100% of the dose in the `.jdi` file across:

Array number 2 (as it appears in the jdf file)	<code>jeolrhul_modulate_array 2 100 doseFile.jdi*</code>
---	--

All arrays that use pattern A (as set in “ <code>Jod Editor</code> ”)	<code>jeolrhul_modulate_pattern A 100 doseFile.jdi*</code>
--	--

The specifier \* is only needed if there are multiple jdi files files in the folder.

6. Compile the program in “`Jod Editor`” by clicking the black arrow ►

**Do not save** as it will overwrite the `.jdf` file.

CHAPTER 5

# BONDING DC SAMPLE FOR DIPPING

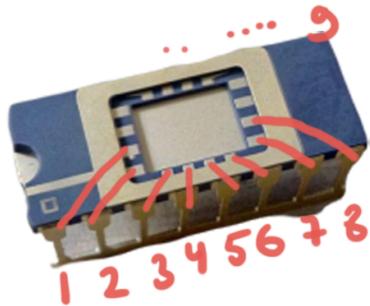


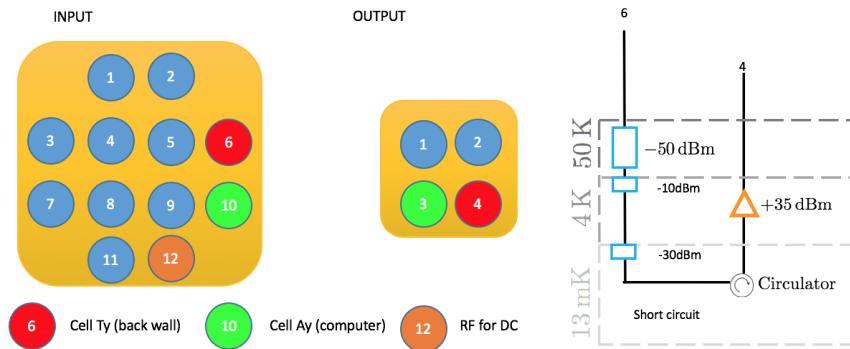
Figure 5: First contact is marked with a  $\square$  (outside) and a little contact marker on the inside.

- Glue sample on the GE Varnish;
- **Do not touch legs when mounting;**
- Make sure orientation is correct when you clip onto the dipping stick.

CHAPTER 6

# SYSTEM AND AMPLIFIERS

The connections from the top of the system are as follows



The attenuator markings, which are attached to the various plate, have the last number depicting the attenuation. **Note, that it can be 0dB!!!**



**Turn amplifiers off when handling them!**

In order to turn both the room temp and cold amplifiers on, we need to apply voltages

1. **LNF-LNR1\_15A** Climb up on the ladder → turn the power supply on → turn the small “on” buttons at the bottom of the amplifier to “on” at the same time;

Left display:2.44V Right display:2.67V

2. There are two LNF-LNR1\_15A amplifiers:

- Input 10, Output 3, Cell Ay, 337 V, closer to computer;

- Input 6, Output 4, Cell Ty, 330V, closer to back wall;

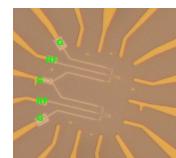
On each line there is a 50dB attenuator in the top hood, 10dBm on the 4K plate (first grey plate), 30dB on the 13mK plate. Turn on the correct switch on the grey box;

3. My AOX-010120 amplifier just needs 5 V from any supply.

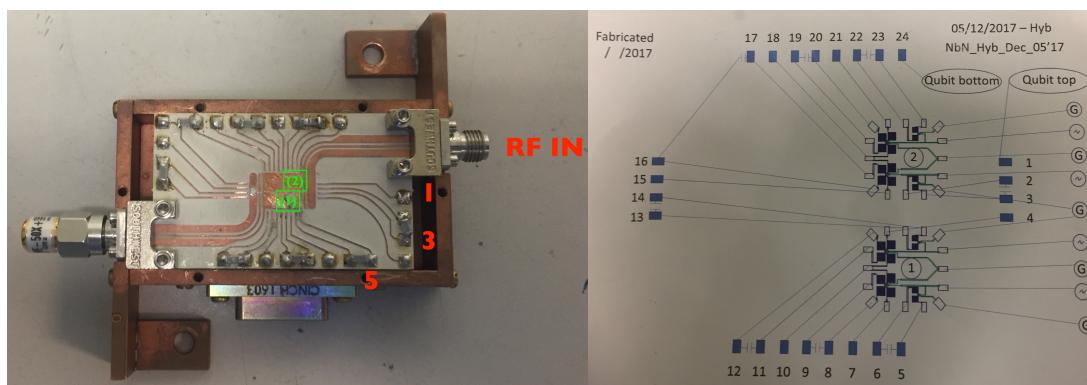
CHAPTER 7

# DC PCB

In the designs, the RF lines and GROUND are on the LEFT-HAND SIDE, and therefore the chips need to be flipped so that RF is on the RIGHT!



- The RF bias is on the RHS of the PCB;
- Numeration of contacts on the PCB begin below the RF line and goes clockwise;
- Position 2 is on top, Position 1 is on bottom (remember to flip the chips);
- **Attach with small drop of resin so that chip 1 and chip 2 are exposed to contacts 1,2,3,4;**
- Remove with scalpel and wash chips in acetone.



CHAPTER 8

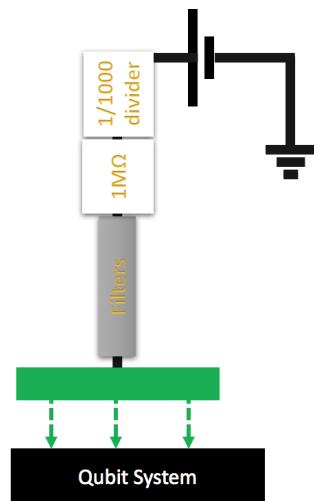
# ETHERNET

Devices are connected via one breakout ethernet box to computers with DNS name 196.168.0.64

- VNA 196.168.0.3
- Blueforce 192.168.0.4
- PC Rais 192.168.0.2
- SPA 192.168.0.6
- My one 192.168.0.1
- Generator 192.168.0.7
- Pulse generator 192.168.0.8

# ADDING GATE VOLTAGE TO QUBITS

For some experiments we add a gate voltage to the system. The circuit for this setup is the following:



The resistor is there to damped any noise. The voltage  $\approx 5$  V is then felt by the qubit system across from the gate electrode.

CHAPTER 10

# DADS WONDERFUL 4 POINT

## MEASUREMENT SETUP

The following setup is used for all kinds of current/voltage measurements in a system. The four terminal approach allows one to evaluate the voltage drop across the samples and the current going through it, bypassing the voltage drop across any wires in the system by using very large resistors.

The scheme of operation is shown below. The setup is placed in a box, with inputs for the  $V_{Iout}$  and  $V_{out}$ .

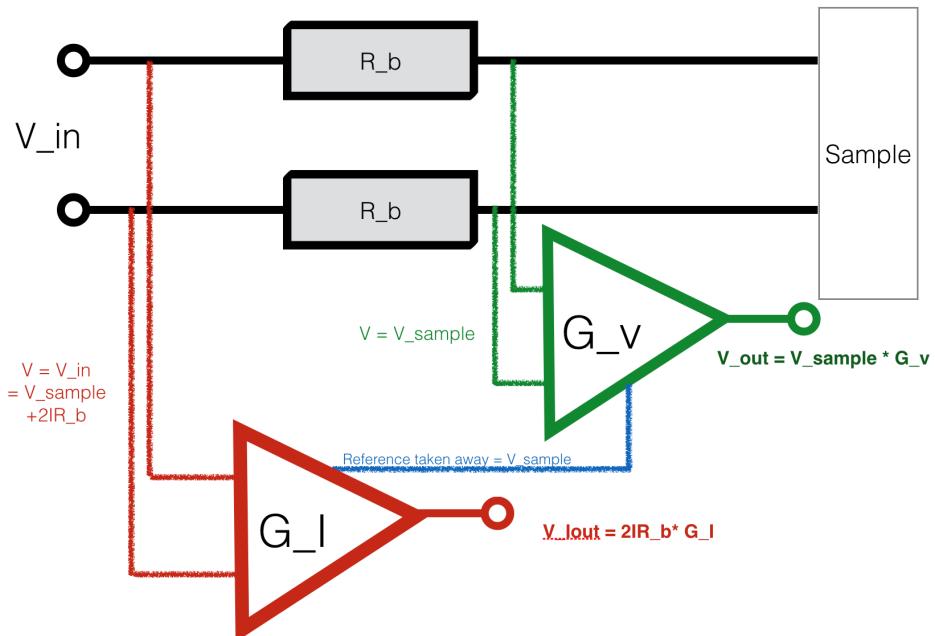


Figure 6: Essentially this is a four terminal measurement configuration, where the voltage is measured directly across the sample, and the current is measured via bias resistors, which all but nullify the internal resistances of the wires, to get a measurement going.

The setup is connected through a box as below. Pins are used to connect laboratory wires with desired sample wires. There important rules are:

- Pins at 6V+ connects  $V_+$  to the 6th wire/contact on the sample. Refer to a diagram to determine correct connection.
- Whenever changing connections, ground  $V_+$   $V_-$   $I_+$   $I_-$   $G$  by putting in pins at 12V+ 12V- 12I+ 12I- 12G where the 12th wire to the sample is in some way grounded;

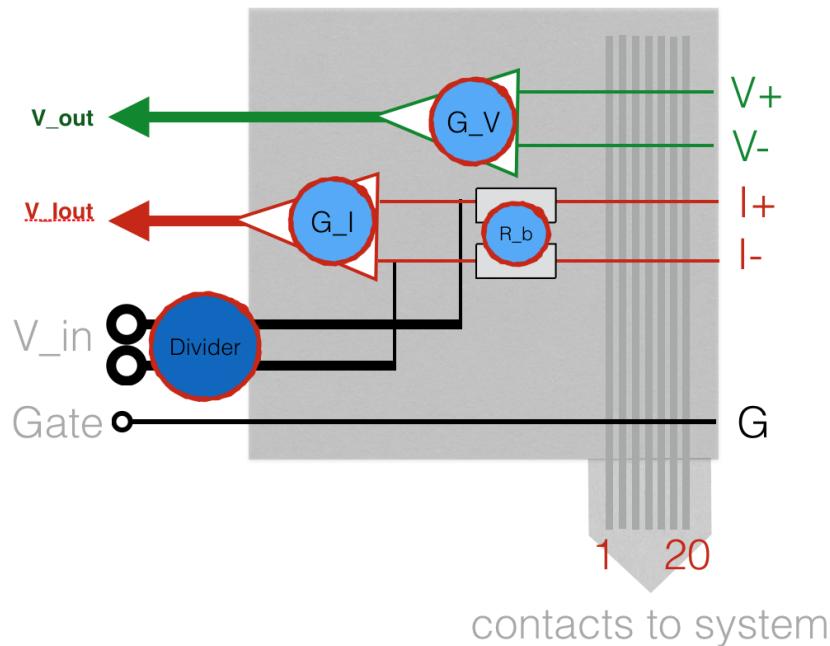


Figure 7: Dials are used to choose resistors and gains. The various wires to the sample area are connected to the laboratory wires via a mesh, that connects two given cables. e.g. for a two terminal measurement, 2V+ 2I+ 3I- 3V- 5G (the coordinates of the pins that we would place) and we would ground all remaining sample wires to a single ground. **VERY IMPORTANT TO GROUND V+ V- etc when changing pins and put all sample wires common.**

- Whenever idle, to avoid potential difference build-up, ground all the sample wires as well e.g. put pins on 1G 2G 3G .. 20G, so that they are all grounded via the 12th sample wire;

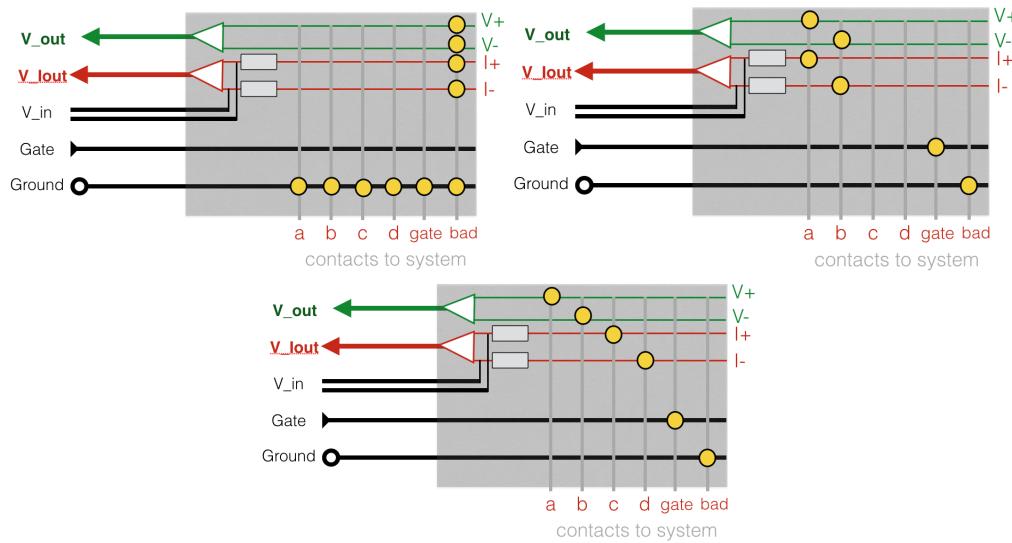
### 10.1 Connecting matrix

The matrix allows one to connect cables in the laboratory to contacts on the samples. In the image below: **Horizontal** - laboratory cables; **Vertical** - contacts to sample.

- **First image shows** how to ground all the sample when not in use and how to common ground the laboratory cables via the bad contact. **When putting new pins in → put in new pins → take out the four common pins to separate them from the ground → take out ground pins.**;
- Configuration for two terminal measurement with gate;
- Configuration for four terminal measurement with gate;

### 10.2 Connection to Pre-Amp in the lab

1. Connect the power cable from the ‘‘blue box’’ +5V to the pre-amp;



2. To  $V_{in}$  connect the voltage cable from "Signal Output 2 Out" on the Lock In;
3.  $V_{iout}$  to PXIE-4462 AI0;
4.  $V_{out}$  (has blue tags) to PXIE-4462 AI3;
5. Combine  $V^+$ ,  $I^+$  and  $V^-$ ,  $I^-$  together in pairs using a  $\pi$ -connector for 2-point measurement, or keep separate for 4-point;
6. Open "ziControl" and click "on" to turn the lock in output on for the second channel (or the one we are using);
7. Load "IV\_va\_VR → IV\_BlueForce";

CHAPTER 11

# DIPPING PROCEDURE

1. Connect orange line from side of dewar to pipe on wall;
2. Open the valve on the pipe and the first valve on the pumps at the back of the room - this will ensure that any evaporated helium is caught back to Harpal's balloon;
3. Take reading on pump;
4. Place orange plum on exhaust of the probe bar - when it starts inflating, there is helium flowing;
5. Open top and place probe. Close it;
6. Slowly lower the rod and then do measurements;
7. After measurements can take rod out - no need to be slow, as before you were heating the helium up;
8. Take reading on the wall of the pump;
9. **Lower thin rod with glove** into the hole at the top of the dewar;
10. Push to lowest point and make a mark;
11. Move up and when the top of the glove changes vibration frequency - **that is the level of helium**, so the difference is the height of helium in dewar;
12. Measure the length and read off dewar to get capacity;

CHAPTER 12

# LOCK-IN ZURICH

A lock in amplifier, adds a AC signal to the initial one, and then, from the output from the system, filters out the components at the same frequency. This is a good way to remove noise. The device is controlled solely from the ZI Control Panel. Any reading from the lock is has already been processed.

What happens is we mix in a signal with the input one

$$V_0 \rightarrow V_0 + V_L e^{i\omega_L t}.$$

This signal with the added AC component is fed into the system. The current and voltage measured out the output will be of the form

$$V_{\text{out}} = \sum_n V_n^{\text{out}} e^{i\omega_n t + \delta_n},$$

which is a mixture of signals from different noise frequencies. Somewhere the signal at the lock in frequency is encoded - the actual response of the system we want to measure. The lock in multiplies  $V_{\text{out}}$  with the original signal and integrates over a set time period

$$\begin{aligned} & \frac{1}{T} \sum_n \int_0^T V_L V_n^{\text{out}} e^{i\delta_n} e^{i(\omega_n - \omega_L)t} dt \\ &= \sum_n V_L V_n^{\text{out}} e^{i\delta_n} \int_0^T e^{i(\omega_n - \omega_L)t} \frac{dt}{T} \\ &= \sum_n V_L V_n^{\text{out}} e^{i\delta_n} \delta_{L,n} \\ &= V_L V_L^{\text{out}} e^{i\delta_L}, \end{aligned}$$

where we can remove  $V_L$  which is known, leaving

$$V_L^{\text{out}} e^{i\delta_L} \equiv V_{\text{signal}} e^{i\delta},$$

the noise free signal from the system i.e. the amplitude and phase of the systems oscillations due to the changing driving current/voltage. All the oscillations at other frequencies have been averaged out.

The lock will present this value as either the XY components, or R,  $\theta$  components.

## 12.1 Tuning parameters on control panel

- Signal inputs

- Preamplifiers → None. **Be sure to select this in the options, otherwise incorrect demodulation will occur** e.g. choose “DIR” not “PRE” in options;
- Scaling+units → Not needed;
- Range/Sensitivity → Its the peak to peak voltage input (from the system we are measuring) that will be boosted to 10V within the lock in. E.g if 3V is selected, it is boosted to 10V for the lock in calculations, but then normalised back to 3V. **I used 5mV for dV, and 10mV for dI in Jan 2017.** You want to make this value the biggest value of the signal in the system e.g. if signal is 100mV, put it at 200mV.
- AC or Diff → what type of measurements we are making. Usually AC.
- Frequency
  - Internal → The internal frequency that is mixed in. **19.0101Hz**
  - Demodulators → There are 6 blocks in the lock in that perform the demodulation (extraction of signal at the lock in frequency). Tick the ones that are going to be used for each input. Select the time for this. 33ms to 238ms. **Ensure that this time is much smaller than the time of your measurement on LabView. If we are stepping the magnetic field per say every 1ns, then the lock in will be averaging for far too long!**

The demodulators are mapped out output Aux1/2/3/4 in “Auxillary/IO”. Normally we choose Demodulator1 and Demodulator4. Twist the **phase shift** in order to maximise X or Y signal (or just choose *R*).
- Filters
  - 24dB/Oct filters
  - Time constant for averaging is discussed above.
- Mixing component - there are two boxes. With each box you control one add/out module. For each module you apply a DC signal (feed into **add**), mix in the AC component and give it out at **out**.
  - Set range for the maximum output voltage;
  - Peak to peak AC → the peak to peak voltage of the AC signal. Make such its smaller than the original signal.
  - Add AC component → ON
  - Turn output on → ON
- Auxillary OI - select which demodulator results you output to which output gates. Select X, Y, R or Θ.

## 12.2 Cable connections

- Connect the DC cable with the bias signal (if any) to one of the “Add” inputs. This is the initial signal, to which the AC component will be added;
- Draw a cable from “Out” port of the Lock-In to the system;
- Draw a readout cable from the system to the “+/-In” port of the lock in. This wire carries the signal that the lock in is going to demodulate. Take care - since no pre amplifier is used usually, do not connect to any pre-amplifier modules;
- Read signal filtered by the lock in from one of its “Aux” cables.

## 12.3 Using oscilloscope to measure DC

Feed in the current and voltage lines to the oscilloscope → choose XY mode in order to plot one against the other. If the contact is open, then current,  $I$ , and voltage,  $V$ , will be creating a lissajoule figure, due to them being shifted in phase relative to one another.

CHAPTER 13

# SPINNING RESIST

- Turn on the vacuum buttons;
- Select program and position wafer;
- Do not touch the metallic buttons → click on the screen pump to activate it - left button on screen (green and shows injection);
- Click green arrow to start spinning (red stop sign to stop);
- Once spinning is finished, press the leftmost button on screen to deactivate vacuum;
- Turn off the pump with the switch under the fume cupboard

Clean samples with acetone°C for 10 minutes, and then wash with isopropanol (spray and spray again with pipette). Wash things with the water gun. Don't need to wash isopropanol dishes.

IPA = 2-propanol = Isopropanol

In case of contamination, wash off with relevant resist remover (AR 600-71 for ARP6200 for example).

## 13.1 Placing resist

1. Get the sample, clean in propanol and dry with air gun.
2. Turn on baking tray (e.g. 170°C), by holding down set and turning dial.
3. Choose correct program (e.g 4500rpm) on the **spin controller** → D → E → E → “Program number” → E. Program numbers are deciphered on the tissue paper next to the machine.
4. Place sample on the spinner. Ensure that a suitable **base** has been chosen - not too big or small - **the sample must fully cover the base**;
5. Put on the resist. For the 2D flakes, we used copolymer 13%/PMMA 4%. For other ones we used ZEP. Use clean syringe. **Do not touch the end of the pipette. Do not go into the solution multiple times - take what is needed in one move!**
6. Turn on the black plug, so that the pump sucks the sample to the base!

7. Press the green button to begin the two minute cycle.
8. Place on the baking tray and cover with a foil hat. Time for 10 minutes.
9. In the meantime clean the base. Acetone on a tissue or in a dish and put the base in
10. Put on a healthy scratch for focusing in SEM. Check with optical microscope and remember orientation.
11. Turn off the heater, the rotator.

Proceed to SEM, in order to perform e-beam lithography. Once complete, its time for development, to cut out the exposed holes in the resist.

### 13.2 Developing

1. Dunk in developer, which varies. For the 2D flake sample, we used T(Toulene):IPA(Isopropanol=2-propanol) 1:3 for 10 seconds, then clean with isopropanol to remove first layer. Then, 7% H<sub>2</sub>O in IPA for 20 seconds and isopropanol to develop the second layer.
2. Acetone will remove all of the layers of resist

Then one proceeds to evaporation. This can be done on the Plassys (Sec.20) or on the Edwards machine (Sec.19). One deposits a film, after which lift off, of the remaining resist is performed. For flake contacts we did 10nm titanium and 80nm aluminium

### 13.3 Lift off

1. To remove aluminium, use photoresist developer 1min and rinse with water.
2. To remove ZEP, use pixelen for 30sec.
3. To remove anything use acetone. Put the dish with a lid to bake for 10 minutes. Everything should come off by itself.
4. Rinse in isopropanol.
5. Look in microscope for result.

CHAPTER 14

# RHUL UV LAMP

1. Turn on from the RHS on the back;
2. Pull out the front tray;
3. Put sample on the tissue paper;
4. Align mask, so that the **shiny/mirror side is facing up (metal on the bottom)**;
5. Put on the heavy mask vacuum pump from the other station to press the mask to the wafer;
6. Slide tray in → slide top tray out to begin exposing → close the shutter once done.

CHAPTER 15

# RHUL OLD SCANNING ELECTRON MICROSCOPE

SEM is used to make images, or to trace out the desired pattern loaded from nanomaker. In this section, we describe how to load and prepare the SEM for tasks.

1. If vacuum is bad ‘‘Sample’’ → ‘‘Specimen chamber’’ → ‘‘stage drawout’’ → ‘‘evac’’ to pump the machine
2. If “HT ON” is not working, its because nanomaker has control of the machine. Go to nanomaker → ‘‘File’’ → ‘‘Exposure’’ → ‘‘Hardware control’’ → ‘‘ExtScanOff’’ → ‘‘Beam On’’.
3. If vaccuum system halted → quit program → turn SEM off and then on with key → usual pumping begins;
4.
  - **Aperture 1** for high detailed images. **Do not exceed 32 spot size!**
  - **Aperture 2** has no restriction on current
5.
  - **Scan 1** for focusing
  - **Scan 2** for general movement
  - **Scan 3** for high quality image. **Click freeze to freeze the scan**
  - **Scan 4** for high quality image that also freezes
6. RP1 - Rotary pump first pumps the diffusion pump, then the chamber, then the diffusion pump works on the chamber

## Change filament

- “Gun” → “Filament” → press ‘‘Vent’’ to vent gun chamber;
- Lift cap → pull cone out → unscrew **EXTERNAL SCREWS** with alan key, release the flat screw and take out filament;
- Clean with stick polish and cotton pad → wash with acetone so that there is no black;

- Take new filament, put ring on it → dip into the cone **making sure that small indent on filament is on the opposite end to the slot in the cone**;
- Tighten external screws and flat screw → use screws in the “caves of the cone” to adjust filament position;
- Slot into SEM → press “evac”.
- When the SEM is working, click “gun” and slide the four sliders to get the maximum brightness to compensate for offsets;

## Beam blanking

For “Beam ON/OFF” on Nanomaker we use a blanker. The small module responsible for it is a box made by Deben.

- Make sure that it reads “Beam blanking ON 200V”;
- Change voltage to 200V by “Plate voltage arrows”;
- If beam blanking is inverted in Nanomaker (beam doesn’t go off when pressing “beamOff”) → Press “Beam Status - Blank” button;

### 15.1 Loading

1. The loading chamber should be vented already → Evac button on screen should be grey.
2. Put on a healthy scratch on the resist for good focusing if resist thickness is greater than 100nm
3. Attach the sample onto the doughnut shaped container. Screw on well. Top of sample, must be near the end of the doughnut that is **symmetrical**. Should look like two frog legs. Open door → Slide onto the rails **if it doesn’t want to go in, try a different orientation**. Close the door.
4. Sample → Evac → Airlock chamber, will evacuate the chamber the sample was loaded in to a low pressure. It will beep when done and button stays green. Takes 30sec.
5. Turn the open handle, to open the door from the sample stage to the SEM.
6. Raise rod down. **Do no touch the rod!!!!!!** Move forward and twist to grab hold of the sample. Push the sample all the way in it becomes hard towards the end and **remember to unlock!!!**. Draw the rod out.
7. **CLOSE THE DOOR BETWEEN THE SEM AND THE SAMPLE CHAMBER!!**
8. Wait 10 minutes for the SEM to pump to low pressure again.
9. Initial position → Go, to move the sample to the operational area.

## 15.2 Calibrating

The following steps calibrate the SEM for operation.

1. First of all set the current and voltage to the required values. This is done at the bottom of the program on the screen.  $I \approx 10\text{pA}$  and  $V \approx 30\text{keV}$ . The Working Distance (WD)  $\approx 20\text{mm}$ . For the 2D flakes, we were at 24pA. **The lower the current, the better the precision.** Push the MDN and AVG buttons on current meter to average readings.
2. Change working distance to  $20\mu\text{m}$  for general and  $10\mu\text{m}$  for fine structures like meanders;
3. **Turn the SEM on by clicking the HT ON button.**
4. Choose the correct aperture, by pulling lever on the side of the SEM towards you and twisting to the desired selection. Aperture 1 is the smaller - has the best precision. **Do not exceed 32 spot size.** Aperture 2 is larger and can sustain spot sizes greater than 40 and is used for imaging.
5. **Ensure that X/Y is chosen on the controller for the movement.**
6. Go to the Coulomb dot (black dot), and zoom in on it. Check that the current is the value that you selected.
7. Press ACB button, which automatically adjust the brightness and contrast.
8. Press R button on the keyboard and align the structure. If needed, click on the sample location on the SEM screen, and manually enter the rotation in degrees that is required.
9. Zoom to  $\approx x200000$  onto a nice edgy structure like Rais dots
10. **Wobbling** - Tool->OL Wobbler, will make the image oscillate - essentially if the aperture is at an angle, then going in and out of focus will have the effect of shifting the image. Turn the dials on the rod that sticks out the SEM to reduce the wobbling as much as possible. Turn the wobbler off.
11. **Astigmatism and focus** - Press scan 1, to go to the near field. Hold down the focus button, and move up and down to focus. If the focus is different in the horizontal and vertical directions, do the same for the X and Y astigmatism.
12. **Gun alignment** - align the gun by changing the X Y and Z, until the current in the coulomb dot, is maximised.

### 15.3 Prepare for use with nanomaker

Now that the SEM is calibrated (should be done after each large movement), we need to prepare it to communicate with nanomaker.

1. Focus on the scratch or near the sample at x100000;
2. Go to the required magnification. E.g. x4000. For graphene flakes it was x350. **Inst Mag on the keyboard to remember this value.** This is useful if you need a very high magnification during exposure, but you can't use it during focusing as it would expose the whole resist.
3. Move the required structure. INST MAG and **quickly Double click** to center without overexposing.
4. **On Nanomaker in Sec.16 click BEAM OFF → INST MAG (if required) → EXT SCAN ON**

### 15.4 Ending session

1. Zoom out and **HT off** to turn off the electron gun.
2. **Sample → initial position** to move the sample back for extraction.
3. **Wait 5 minutes** to allow the tungsten cathode to cool. If you begin venting before this time, TuO strings form on the filament,
4. Evacuate the loading chamber **Sample → Airlock chamber → Evac.** It will beep when ready and show green button.
5. Open the shutter, put the rod in **the hold position**, extract. Twist to unlock and place rod.
6. **Close the shutter once finished.**
7. Can take out as soon as required.

### 15.5 Taking image

1. “Scan 4” → “File” → “Save as”;
2. Take data from the computer underneath the desk.

# NANOMAKER

## 16.1 Communication with SEM

To pass on control between the SEM and the nanomaker program:

1. Click the exposure button, or go to File → Exposure.
2. Select Hardware control to open up a small block of buttons
3. To go from SEM to nanomaker: Beam Off → ExtScan On.
4. To go from nanomaker to SEM: ExtScan Off → Beam On.
5. Remember, that if the scan need to be done at a high magnification, to flick the INST Mag button before proceeding.

## 16.2 Marker files

Marker files are used to align the field, so that the design is exposed in the correct area. For example, changing the current will distort the image taken by the SEM.

However, if one definitely knows the position of some markers, e.g. crosses at  $200\mu m$  separation, then one can

- Define that Marker A is at position  $(200, 50)\mu m$  etc.
- After scanning the image with the SEM, click on the image to define where the center of Marker A is.
- The program will stretch, move, twist the image, so that the positions you clicked on the screen get the coordinates  $(200, 50)\mu m$  etc.

Always load the parameter file when creating markers, opening markers etc. This sets the correct field size (the yellow border). **Options → load PAR.**

Now how to create marker files

1. It is crucial that you know what magnification you are working on. Otherwise the position of the markers will be for the incorrect working field.
2. File → new Video control file to create a marker file.

3. **Marker** → Define marker to access the markers in the field. Here you set

- (a) The size of the field that is going to be used. Too big causes too much exposure. Too small, and you wont be able to locate the markers.
- (b) The coordinate of the field area.

By default there is a zero marker for the centre of the field. Use it to set the size of the field.

4. **Add Marker** and define its position (usually determined from the file were the marker was designed) and the size of the image that is taken around that position, to help during alignment. Create as many markers as needed.

5. **Save as a .mrk file.** Ensure that both the file type and the ending .mrk are used.

To use the marker files, load them in nanomaker, and make sure we have control on the SEM that is positioned close to the markers.

1. **Video** → **set align parameters** → **reset** to reset any previous adjustments. Do not do this, if you want the field orientation to remain the same.
2. **Video** → **Get all Video**, takes a scan of the regions where we defined the markers.
3. For fields were markers are very close to exposure field **for initial alignment take video on one marker to not expose others** i.e. press ‘‘v’’ instead of ‘‘a’’ and apply shift → then do the alignment with all the markers;
4. If you dont want to use certain markers for aligning, don’t set the ‘‘s’’ center point on them this may be required if many markers keep not aligning;
5. For each marker **Mark** → **select center**, and select where the marker is on the image. **Video→ set alignment parameters** → **reset zoom for large patterns ‘‘x=1, y=1’’ to prevent resizing pattern BUT FOR SMALL PATTERNS DONT DO THIS!!!!** → **calculate** to apply the changes.
6. **Video** → **Get all Video**, to see how the recalculated field aligns with the defined markers. Keep repeating. With each iteration, twisting etc will make sure that the markers you defined, and the markers you select on the screen are aligned. **Assumes that we are always working a fixed magnitude.** We can no expose.

### 16.3 Taking an image

**Always use aperture 2 for currents above 32pA!!!!**

- Click ‘‘SRT’’ to rotate the image;
- File → new Video control file to create a blank file.
- ‘‘Mark’’ → ‘‘Define Mark’’ and select  $460 \times 320 \mu\text{m}$  to fill up whole sector with image;
- Select resolution of image using ‘‘Size [pix]’’;
- Video → Get All Video takes an image of the specified size.
- Save as a .tif and ensure that the file type is also TIF.

## 16.4 Pattern

- From autocad, save the image in format ‘‘R12/LT2 DXF’’, by using ‘‘saveAs’’ and clicking on the drop down arrow next to the file name;
- File → New database to create a blank sheet for working on.
- Options → Load PAR → 350.par to load the parameter files for resist, wafer, magnification etc. MUST DO. Choose parameter file in correspondence with the required magnification 350 for large field, 800 for small field.
- Add a background (for example if you want to design on top of an image that was already taken) View → redraw → background
- View → Draw Layers in order to shift between different layers on the image. Convenient to have all the files in one place. To create a new layer, draw object edit → change attributes and set new layer.
- Draw using the standard tools. If overlaps occur, then the regions will be given a higher dose. See proximity correction below to overcome this. To repeat pattern ‘‘Transform numeric’’ → set the ‘‘dose increment’’ at each transformation
- Once drawn, there are two options to set the % doses:
  1. Apply the proximity correction. Proximity → Correction → Recommended to get the menu to pop up. Here it depends on the lithography that is being made. But for example for the 2D flakes:
    - $\alpha = 0.05 \mu\text{m}$
    - Resist = PMMA 30-40keV
    - Substrate = Silicon
    - Height =  $1 \mu\text{m}$  OF THE RESIST! Use thickness vs rotation speed graphs to determine this

**Apply proximity correction by pressing SET** in order for the new parameters to be used.  
The regions should change colour once this is done.

2. For fine structures i.e. DC samples etc, the dose must be set manually. Use the above proximity correction procedure to evaluate the required doses - one will find that the doses are uniform (the structures are so small, that one does not need to account for the wide backscattered Gaussian)
  - Select structures → ‘‘edit→ change attributes → set dose’’. The doses we need to set are:

<b>Structure size</b>	$\geq 0.2 \mu\text{m}$	$0.2 \mu\text{m}$	$\leq 0.1 \mu\text{m}$
<b>Dose %</b>	166	181	200

## 16.5 Preparing and exposing parameters

1. Options → Exposure and video → ‘‘Step/Times’’ to set the exposure parameters (note that this is different from the proximity correction above. Above we just varied the % dosage that we apply to shapes. Here we set the base dose (the 100% from which the absolute value of the % doses will be derived) that the electron beam delivers). This will vary from lithography to lithography, and the values we use are the same as for the proximity correction e.g.

- $\alpha = 0.05 \mu\text{m}$
- Resist = PMMA 10-40keV
- Substrate = Silicon
- Height =  $0.5 \mu\text{m}$
- I = 24pA
- Dose =  $90 \mu\text{As/cm}^2$
- Sensitivity = 200

**Click OK → click the three buttons next to numerical values to set parameters!!!**

2. If the “area dwell time” is  $\geq 10 \mu\text{s}$ , then you need to increase the step size in the step menu e.g. from 0.1 to  $0.125 \mu\text{m}$ , so that the beam doesn’t jump around too fast.
3. Options → Load PAR → 350.par to load the parameter files for resist, wafer, magnification etc. **MUST DO.** Choose parameter file in correspondence with the required magnification 350 for large field, 800 for small field.
4. Do the marker alignment described above
5. Layer to select the layer of the drawing to be exposed.

6. A 100% dose corresponds to the following formula:

$$\text{Dose} = \frac{I \times \tau}{\text{Pixel}^2},$$

where we set **Dose**, **I** in “options → times → recommended” and **pixel** in “step size”. The dwell time  $\tau$  evaluated from this must be  $\geq 10\mu\text{s}$  or the beam will jump around too fast

7. For small structures ‘‘Options’’ → choose x or y direction → ‘‘simulate’’ (in exposure window) to trace out how beam will jump. Choose X or Y direction where there are fewer jumps (beam jumping is bad). Normally no optimistaion is the best!
8. Finally click “start” and don’t touch the table.

## 16.6 Example design for flakes

1. Options → Load PAR → 350.par;
2. Load sample and take image as .tif;
3. Unload sample;
4. Start designing (ensure that you still have ‘‘350.par’’) with the tif image as background;
5. Apply proximity correction;
6. Use screen pointer to find the coordinates of the markers that are in the image. Write them down;
7. Create marker files, and put the markers in the coordinates taken above - this means that the pattern you drew will be mapped to the correct markers;
8. Load and expose.

CHAPTER 17

# RHUL PLASMA ETCHER

If the machine is already on do `stop → evacuate` and you are all set

## To turn on from scratch

1. Open panel and press green on button;
2. Wait for computer to load → ignore red alert → stop → evacuate;
3. Once base pressure reached → stop → vent;

### 17.1 Running

1. Turn on the [digital one cooler] so that plasma source keeps cool;
2. Run your process once to clean chamber;
3. Then the resist strip for 2 minutes to finish cleanup;
4. Stop → Vent;
5. Chamber up → Press two buttons simultaneously to open hatch;
6. Load sample → close lid (chamber down) → stop → evacuate → enter the wafer name → ready when indicator text that base pressure reached  $\approx 10^{-5}$ Torr;
7. Process → Recipe → Load → choose recipe → click in the menu of items to edit process → set power, gas flow, time, pressure;
8. Run → yellow alert shows up when done → click accept;
9. If we want to repeat run click arrow.

### 17.2 Unload

1. Stop → vent → push buttons to raise lid and unload;
2. Turn off cooler under the table;
3. Chamber down → stop → evacuate;
4. If leaving the machine click cancel in the menu that comes up.

To turn off fully, make sure chamber is evacuated and press the big red off button, under the front panel of the etcher.

CHAPTER 18

# RHUL NEW EDWARDS DEPOSITIONS

Machine is located in clean room, used for depositing gold, nickel, titanium aluminium. **Very important** to get the valve system in the right order.

## 18.1 Switching machine on

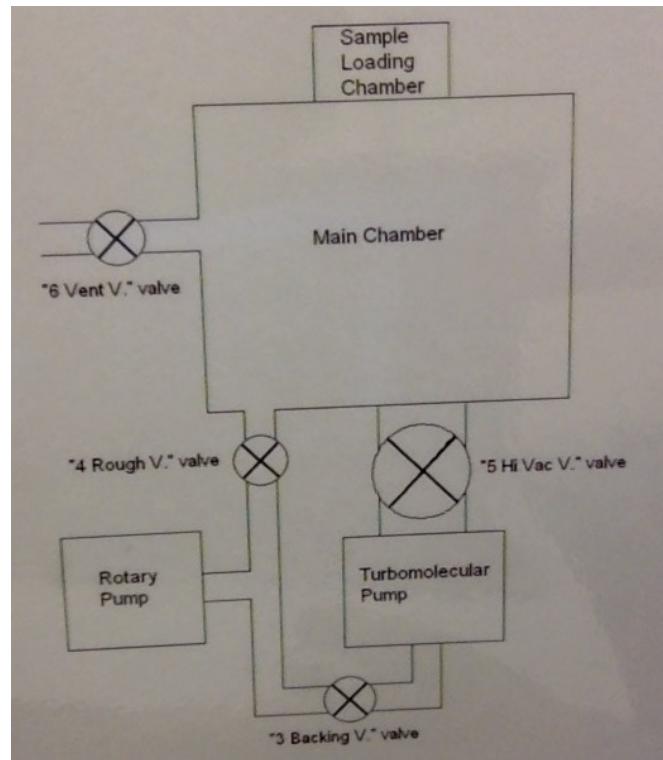
The machine is initially in the off state. First we need to get the pumps of the machine up and running.

1. On the black ‘button board’ turn the dial on the top middle sector from 0 to 1 to turn the machine on.
2. The green screen directly to the right should light up. Select ‘MANUAL MODE’ out of the possible options.
3. Scroll to ‘‘RELAY-INPUTS’’ → Press ‘‘YES’’. **Check that everything is “OFF”!**
4. Go to ‘‘1 ROT PUMP’’ option → press ‘‘ON’’. This turns on the rotary pump.
5. Go to ‘‘3 BACKING V.’’ option → press ‘‘ON’’. Now the turbo molecular pump is being pumped.
6. Go behind the machine, and check that the black box is receiving power. Red light below ‘POWER IN’ should be on.
7. Open up the chamber directly under the main chamber. At the very back is the turbo molecular pump switch - **A red switch**. Flick it **down** to start the turbo molecular pump. If it starts flashing red, turn it on and off again.

## 18.2 Loading

To load, we need to vent the chamber and open the door. **Prior to loading double check that ‘‘4 ROUGH V.’’ ‘‘5 HIGH VAC V.’’ are off!**

1. Go to ‘‘6 VENT V’’ options → Will read ‘‘OFF’’ → Press ‘‘YES’’ → Will go to ‘‘ON’’;
2. Press ‘‘NO’’ → Will read ‘‘MONITOR SYSTEM’’ → Press ‘‘YES’’ to enter menu. Chamber pressure displayed;
3. When pressure gauge read  $10^3$ MB, Press ‘‘NO’’.



4. Go to "RELAY/INPUTS" → Press "YES";
5. Go to "6 VENT V." option → Reads "ON" → Press "YES" → Now reads "OFF". **THIS IS SO WE DONT FORGET TO CLOSE THE VALVE AFTERWARDS AND SCREW UP THE TURBO PUMP;**
6. Chamber can now be opened and loaded;
7. Check the material level by Go to TURRET CONTROL PANEL → Select material → Press the "0/1 BUTTON" → The motor switches on. → Remember to switch the "0/1 BUTTON" off.

### 18.3 Pumping the main Chamber

Once the sample is loaded

1. Go to "RELAY/INPUTS" → Press "YES".
2. Go to "6 VENT V." option → Check if reads "OFF" (If not press "YES" to set to "OFF"). This is to prevent the venting of the main chamber.
3. Go to "3 BACKING V." option → Press "YES" → Now reads "OFF". This is to isolate the turbo pump from the main chamber.

4. Go to “4. ROUGH V.” option → Press “YES” → Now reads “ON”. This causes the rotary pump to pump the main chamber.
5. Press “NO” Now reads “MONITOR SYSTEM” → Press “YES” → Chamber pressure displayed. Wait until 0.5MB reached.
6. Press “NO” → Go to “RELAY/INPUTS” → Press “YES”.
7. Go to “4. ROUGH V.” → Press “YES” → Now reads “OFF”. **Wait 10-15 seconds.** This prepares the rotary pump for helping the turbo one.
8. Go to “3 BACKING V.” option → Press “YES” → Now reads “ON”. We now pump the turbo pump with the normal one.
9. Go to “5 HIGH VAC V.” option → Press “YES” → Now reads “ON”. The turbo pump is now pumping the main chamber.
10. Press “NO” → Go to “MONITOR SYSTEM” → Press “YES” → **Check pressure is decreasing.**
11. Press “NO” → Go to “PENNING CONTROL” menu → Press “YES”.
12. Press “YES” → Now reads “HEAD ON”. This turns on the sensitive pressure meter. If it doesn’t turn on, repeat until it does.
13. Press “NO” → Go to “MONITOR SYSTEM” → Press “YES” → **Leave to pump until  $5 \times 10^{-5}$  MBar.**

#### 18.4 Crucible deposition

1. **TURRET CONTROL** is where one selects the material to deposition. Turn the dial to the desired position → Press the “0/1 Button” to activate the motor and make it turn. Remember to turn it off afterwards though. On means the motor is running, o\l means it is not moving. A yellow light indicates the turret position;
2. **SWEEP CONTROL** is where one adjusts the beam. The raw settings are
  - X = z waveform, **15 frequency**, middle amplitude;
  - Y = sinusoid waveform, **8 frequency**, middle amplitude.
3. **SOURCE CONTROL** is where one sets the accelerating voltage and the current for crucible deposition.

4. **SOURCE SHUTTER** → Press middle button to set it into remote mode. This way whenever the required thickness is reached (via LabView or manual procedure) the shutter will close automatically. If you want to control the shutter manually, Do NOT press the middle button. Instead be prepared to Press SS1 button (left hand side) to open and close to the shutter manually.
5. Activate the “FTM7” where one sets the deposition parameters. Click on ‘‘DATA’’ button to change between the menus. Alternatively run “FTM7\_set\_parameters.vi” from LabView to set the material and thickness!
  - **Rate** gives the current deposition rate;
  - **Layer** is what material is being deposited. There is a sheet in the lab saying what layer corresponds to what material. E.g. for Au it is layer 4. **Set to the required material!**;
  - **Density and z-Value (acoustic impedance)** are set depending on the layer chosen. They depend on the material used - **set to the required material.**;
  - **Terminate** is where we set the thickness after which to close the shutter. **Set the required thickness.**;
  - **Tooling** sets the ratio of the distances of the quartz thickness crystal and the samples from the crucible. **Set to 1.0**
  - **xTal** selects which of the 2 crystals we are going to use. **By default set to 1 - the crystal in the right hand side of the chamber**
  - **Usage** indicates how much the crystal has been used out of 100%.

With this basic setup, one can proceed via two routes to perform the deposition.

#### 18.4.1 Gun deposition (i.e. we do it manually)

1. Set the deposition parameters on ‘‘FTM7’’.
2. Go to ‘‘SWEEP CONTROL’’ panel turn the dial 0→ 1.
3. Go to ‘‘SOURCE CONTROL’’ panel → Press ‘‘ON/OFF’’.
4. Press ‘‘GUN’’ button to allow local control → Voltage should jump to **5kV**.
5. Slowly ramp up the current 0mA→ 20mA→ 40mA→ **No more than 120mA!** and monitor the deposition rate on the ‘‘FTM7’’ panel.
6. When a steady reading is produced (0.10nm/s) Press ‘‘RUN’’ on the ‘‘FTM7’’ panel to open the shutter. Deposition proceeds, and the shutter will close automatically once the **set thickness** is

**reached.** Shutter can be out in manual mode by ‘unpressing’ the “REMOTE SHUTTER” button and operating the “SS1” button.

7. Make sure that there are no explosions in the crucible. Lower current if required.
8. Once done, shutter will close. Slowly ramp the current down to 0 → Turn off “GUN” → Turn off “SOURCE CONTROL” → Turn off “SWEEP CONTROL”.

#### 18.4.2 Local/Remote deposition (usingLabView)

LabView is when the deposition is controlled from the LabView program.

1. Log into “Administrator” with empty password.
2. Load Evaporation Control Program.
3. Choose material → choose thickness → choose rate. Do not worry about the turret option – then turret you have set manually is the one that will be used in the deposition. Run program → press start → wait until shutter lights turns on and off → stop program to set parameters on “FTM7”.
4. Go to “SOURCE CONTROL” panel → Press “ON/OFF” → Voltage should jump to **5kV**.
5. Press “LOCAL/REMOTE” button to allow LabView to control the current.
6. RUN the program. The rate will be reached (current 10-100mA) → Shutter opened → Set thickness deposited → Shutter closed → current ramped down. If an error occurs, manually lower the current by slowly lowering current value in “Electron Gun.vi” to 0mA.
7. Turn off “REMOVE/LOCAL” → Turn off “SOURCE CONTROL” → Turn off “SWEEP CONTROL”.

#### 18.5 Boat or spiral deposition

There is no shutter for this deposition! We do not touch the source control panel, but use the one with HT, LT and big 0-11 dial

- Set the deposition parameters on “FTM7”.
- Ensure that the middle source shutter button is NOT pressed → press “Run” on “FTM7” to begin accumulation from 0;
- The front and back voltage supplies are chosen using LT selectors “front” and “back”, respectivily;
- Choose “LT” on the LT-0-HT dial to activate the voltage supply;

- “Reset” and begin ramping up the current;
- Once “FTM7” shows the required thickness → **press “trip”** and turn the dial to LT-0-HT

## 18.6 Venting the main chamber

Once the deposition is performed **wait 5 minutes** before taking the sample out.

1. Press “NO” → “MONITOR SYSTEM” → Go to “PENNING CONTROL” menu → Press “YES” to enter.
2. “HEAD ON” will be displayed → Press “YES” → Now reads “HEAD OFF”. We need to turn off the sensitive gauge to avoid damaging it.
3. Press “NO” → Go to “RELAY/INPUTS” → Press “YES”.
4. Go to “5 HIGH VAC V.” option → Will read “ON” → Press “YES” → Will go to “OFF”. Thus we stop pumping the main chamber. **Wait 40 seconds.**
5. Go to “6 VENT V.” option → Will read “OFF” → Press “YES” → Will go to “ON”. The chamber begins to vent.
6. Press “NO” → Will read “MONITOR SYSTEM” → Press “YES” to enter menu. Chamber pressure displayed.
7. When pressure gauge read  $10^3$ MB, Press “NO”.
8. Go to “RELAY/INPUTS” → Press “YES”.
9. Go to “6 VENT V.” option → Reads “ON” → Press “YES” → Now reads “OFF”.

THIS IS SO WE DONT FORGET TO CLOSE THE VALVE AFTERWARDS AND SCREW UP THE TURBO PUMP.

10. Chamber can now be opened and loaded.

Before leaving, remember to rough pump the main chamber and **turn on the turbo molecular pump to pump the main chamber!** If you don’t put the backing on, it will de pressurise over time and damage the pump.

CHAPTER 19

# RHUL OLED EDWARDS DEPOSITER

- Remember to follow the arrow on the handle which points to current pump configuration
- If thickness monitor is not responding click **shutter** button multiple times until it shows **close**.

## Starting up

- Turn on the Edwards Plug → open front door and press Green button (its the breaker);
- Turn on the pump with in a switch in the back corridor;

### 19.1 Preparation

1. Turn on diffusion pump (yellow handle). It needs to be constantly pumped by another pump (we never turn it off. if needed, pull out its plug). Give 20 mintues to heat up;
2. Air admit to vent chamber → red indicator lamp turns on → wait 2 min;
3. Remove the two bubble cases → **air admit to off** in order to not forget afterwards;
4. Remove chimney → If required unscrew the plasma etch setup. There are two fairly large screws on the bottom of the holding plate and two screws next to the protractor dial. Fully unscrew them and place to one side → shift the plasma etching setup (needle, protractor, base) to side of hole;
5. Screw in the sample holder to a bar that is placed on top of the hole;
6. For spiral get 10cm of the deposited material and wind it onto the spiral coil, ensuring good contact;
7. For boat Top up material;
8. There are three electrodes in the machine. Connect the spiral and boar, one to common, one to one of the leftover electrodes
  - The far back electrode is ground = common
  - Side one is 1;

- Near-back one is 2;
9. Place separator between boat and spiral. It will be lifted up when the diffusion pump is activated and the stage rises up;
  10. MAKE SURE THAT THE CRYSTAL USAGE ON THE THICKNESS MONITOR IS NO MORE THAN 80;
  11. Place chimney so that thickness monitor can see both sources → ensure that shutter is closed;
  12. Place any wiring on the top stage;
  13. Position lids with exclamation sign opposite a small circular pin;

## 19.2 Pumping

1. Turn lever anticlockwise to roughing to begin pumping → check the pirani 10 and black mks box on other depositor for pressure;
2. Turn the “DO NOT USE FORCE” pin out - this relieves the pressure in the gas lines so that there is no leakage (controllers on the wall produce a very good seal);
3. Add 3 scoops of nitrogen to trap oil;
4. Once 200mTorr shows on the mks barometer and the “PIRANI 10” (around 5min) → handle clockwise 360 degrees to hook up diffusion pump;
5. Turn on Penning 8;
6. If the “OERNNING VALVE” doesn’t rush over  $10^{-4}$  then refill the nitrogen trap;
7. Keep track of “PENNING VALVE” → wait for  $8 * 10^{-6}$  torr which takes around 1 hour;

## 19.3 Depositing

1. On the thickness block “LAYER” → use “INC/DEC” to choose the layer. Make sure correct “DENSITY” and “Z-VALUE” show up;
2. Turn the black lever to “source 1” or “source 2” (horizontal positions), depending on what we are going to be depositing;
3. Press yellow “LT” (low voltage) button → press “green” safety button → start ramping the current up. Typically it would reach 20-30% for good deposition;

4. May need to turn handle anticlockwise to lower the stage – the separator might be blocking even dispersion!
5. Open shutter and press “open” on the thickness monitor. Once required thickness is reached, close the shutter manually;
6. Ramp the current down to 0 → Press red “reset” button, so that the green button jumps up → turn LT off;
7. Only after this, may you switch the voltage source;

#### 19.4 Final steps

1. Turn handle to “backing” until it won’t turn no more and wait for 5 minutes to allow stuff to cool → turn off the penning monitor;
2. Turn the “do not use force” knob inwards, to cancel the atmospheric pressure;
3. Press “air admit” to vent the chamber;
4.
  - Remove sample and divider (if used);
  - Remove boat and spiral;
  - Rescrew the plasma setup → put on glass cylinder and top bit;
  - Put chimney back in;
  - Replace bubble and implosion guard.
5. Press “air admit”;
6. Handle to “roughing”, wait for 200mTorr reading on mks → DO NOT LEAVE LIKE THIS!!;
7. Turn off diffusion pump;
8. Turn handle to backing position and leave!

CHAPTER 20

# RHUL PLASYSS DEPOSITER

Machine in separate room. Used for good deposition. For flakes on 28th January we did 10nm of titanium and 80nm of aluminium.

Orient the sample so that the axis of rotation goes parallel to the overlap you want. The sample will rock along this axis, giving overlap either side of the rotation axis.! THIS IS NEEDED FOR CORRECT ANGLE DEPOSITION

Etching may be used to remove oxidised layers prior to main deposition for good ohmic contact.

## 20.1 Starting up

- Turn on “mains” and turn on “disconnector” dial → “start” (green button);
- “Motor” → “Home” to remove warning;
- Log on as “engineer” and password is “password”;
- “Ch Cryo” → “Regen” to start the cryo pump. It purges (fills up with nitrogen) and pumps to remove nitrogen and water vapour;

## 20.2 Loading

- Vent button on the **loadlock process panel** to vent the loadlock for 3 minutes. When lid can be freely lifted up **and the ATM LL orange button above the emergency button is on**, you are ready.
- **Wearing gloves**, remove the base from Plassys by pushing and turning.
- Attach the sample. Ensure that it doesn’t fall off when tipped upside down.
- **In gloves load the base as before. Make sure that the small circular pin on the base is closest to the door of the lab.**
- Close the lid and press the **pump** button. Press lid down for the first part of the pumping. This will vent for 20 or so minutes. **Should be around  $10^{-7}$ mBar when ready for use.**
- **To rotate the stage, go to “planteray” menu. The angle you enter will be halved by the program!**

- Click the two-triangle-facing-each-other symbol between the chambers on the diagram → it should go green, to indicate that the two chambers have been connected;

### 20.3 Creating a process for deposition

In order to make a custom process

- Process editor → Add new process.
- Always have the Pump LL to  $5 \times 10^{-6} mBar$  + Pump Ch to  $5 \times 10^{-7} mBar$
- Insert row to add a new step.
- Go to folder on the left hand side of the screen, and drag the required new processes such as deposit 10nm of aluminium.
- Save as → new process.

### 20.4 Running process

- Run process → select sequence → file → open recipe
- Execute button to run it.
- A series of heating up material, getting the right deposition rate, right vacuum is performed. There are frequent checks to which you must agree.

### 20.5 Ending

- Vent the loadlock and wait for 3 minutes before removing with gloves;
- Make sure you screw on all the plates on the base before replacing;
- Pump the system before leaving → ensure that the turbomolecular regime is reached;
- ‘‘Loadlock’’ → ‘‘Stop’’ to stop pumping of chamber once good pressure is reached in order to save the pump.

## 20.6 Static oxidation

For JJ it is required to oxidise after the first Al layer, and after the whole process is finished. The two options for oxidation are:

- **Static regime** is used, whereby  $\approx 0.3$  or  $10$  mbar (first layer and second layer oxidations) of oxygen is pumped into the chamber and we wait for 10minutes or so.
- **Dynamic regime** where a flow of  $\approx 40\mu\text{bar}$  is shot at the sample.

### 20.6.1 Static setup

For the static case, we need to adjust the needle valve (small turn dial in front of red flow meter) so that the required pressure is reached after 30sec, so that Plassys doesn't overshoot the pressure;

1. Pump the load lock to base pressure;
2. **Close the needle valve by turning it clockwise → unscrew it by  $10^{\circ}\text{C}$  or so;**
3. Click “Oxidation → static” to engage the static mode;
4. Click the two traingles next to the “‘O2’ symbol between Ar and O2 t-junctions so that oxygen is let in;
5. Time, that the pressure in the loadlock reaches 0.3mBar in around 30 seconds;
6. **If needed to reperat “vent” → adjust needle valve → “static oxidation” → “O2 triangles.”**

Once the low pressure oxdiation processes finish in the recipe (0.3 mBar for example) you need to unscrew the needle valve fully by  $180^{\circ}\text{C}$ . Otherwise the very last oxidation process in the cycle, which runs at 10 mBar, will take too long to inject the correct amount of oxygen.

## 20.7 Admitting argon

Sometimes you want to vent to chamber, or flush the argon line.

1. Put the loadlock into “process” mode button;
2. Enter the argon flow rate in the very top box “IBF Ar (20sscm)” → click the red traingles next to the argon

CHAPTER 21

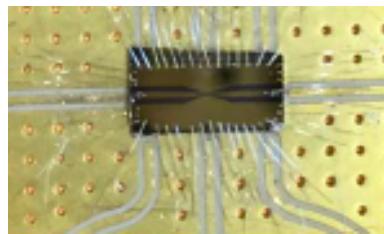
# RHUL WEST BOND BONDING MACHINE

1. Turn on the machine by flicking the switch near ‘‘Did you book your session?’’
2. Turn on pump under machine - it will not make a sound as it only needs to pressurize the tank occasionally. It is a passive element;
3. **Turn the valve horizontal** to connect the pump tank;
4. Secure sample;
5. Typical settings for Aluminum or Gold. **Aluminum is easier to bond with:**
  - Buffer 1 or 3;
  - Power 311;
  - Time 33ms.
6. Touch = one peek = begin bond,              Touch again = double peek = terminate bond;
7. **Move only up or down!;**
8. If the wire pops out or breaks **do not pull the wire out from the tube - its impossible to put back in.** Flick ‘‘Open’’ → put the wire from the back though the very end of the tip (where the hole is) → Flick to ‘‘feed’’;
9. Once done pump off → valve to vertical closed position → power off.

If not bonding try to:

- Rewire;
- Remove needle with Alan key **making sure not to drop it!**
- Clean the needle with acetone, IPA and ultrasound → dry to clean the very tip;
- Replace needle, so top bit sticks out a little bit.

Bong ground planes a much as possible, and 6 bonds for transmission lines as seen below



# RHUL ATOMIC FORCE MICROSCOPE

Positioned at RHUL it can be operated in:

- **Contact mode** where tip scans along surface and the height the tip is moved up and down is monitored.  
*Uses single tip cantilever;*
- **Tapping mode** where the cantilever vibrates up and down and using a lock-in technique we measure the topographical effects that map out the surface;
- **Interleave mode** where there are two scans, first one for the topography, second that uses the initial scan data to work out the magnetisation.

1. Turn on boxes, bottom to top on the back → then the TV.
2. Load up program “V613b21”
3. Place tip holder onto sample holder. *The tip must be facing up;*
4. Unscrew laser on the RHS (the pin actually goes *in* to release the clamp!) → put in the tip holder;
5. “V613B” → “open workspace” → “4thtapping” → click on the yellow microscope to turn on the optical microscope;
6. Choose “scan triple” to monitor 3 pieces of data e.g. height;
7. Align laser (while it is unscrewed from the base)
  - (a) Turn dials on top of laser until the laser light falls on the tip (you can see shadow of tip) to position the laser light on top of the cantilever. You will evidently see a circle split in half. The information on the screen shows the RMS voltage → *maximise it*;
  - (b) Turn dials on the side and monitor the red dot on the screen cross-hairs to position the laser light detector. *Should read 2-6V*. There should be a red laser line in the window on the laser module;
  - (c) Additionally on the screen, the laser light should be at the center of the cantilever;
8. “Navigate” tool and move up and down arrows to move the sample to position by moving the stage;

9. Click “Locate tips” and click arrows to adjust focus on cantilever;
10. Dials on microscope (the far left hand dials facing towards you) to move optical image on the screen so that the two crosses fall along the base of the cantilever tip triangle  
Try to put the optical microscope so that the tip is on the blue dot;
11. “Focus surface” to focus on the sample surface by combination of movement and z up-down;
12. Lower illumination to check that laser shines on the middle of cantilever;
13. “Tune” → set the start and end freq of the natural cantilever frequency → autotune to find it Typical value around 85kHz;
14. Engage to turn scan on → set “amplitude setpoint” to half the one set! ( $\approx 1.2V$ ) and “scan rate” to adjust;
15. The red and blue trace lines should be identical  
Can play with
  - Change units 10th option from bottom from “volts” to “metric”
  - “trace and retrace” to choose what data each channel collects;
  - “Line direction”
  - “Samples per line  $\approx$  lines = 512”;
  - “Scan size”  $\approx 2\mu m$ ;
  - “Integral/proprtional gain” adjust by  $\pm 0.3$  to get maximal alignment of the trace and retrace;
16. To move tip “offset” → drag white square to required region → “execute” Note that the movement is not good, its better to enter the parameters manually in the boxed. + moves the sample up/right relative to the cantilever. - moves the sample down/left relative to the cantilever (down/left on the screen). Up/down is limited to  $2\mu m$ , left/right is limtied to  $1\mu m$ ;
17. If stucture is missed (offset can be  $\pm 1\mu m$  in the X direction and  $\pm 10\mu m$  in the Y direction)
18. Capture to take the image;
19. To turn off exit program → shut down blocks top to bottom → shut down computer. **Restart in the opposite way**;
20. “Gwyddion” to analyse images. The images from the AFM are saved in the “C: capture” folder;

CHAPTER 23

# RHUL PROBE STATION (FOR MEASURING CONTACT RESISTANCE)

Turn on the microscope and the voltage source

- Place sample on bit of foam to prevent leakage to ground;
- **Ground yourself;**
- Move sample with red pin underneath;
- Turn small vertical handles (on the inner side of the red handles) for positioning the pins roughly;
- Lower pins by lowering handles facing the wall - bring into close proximity with surface;
- Turn red 10/4 revs for fine movement and to lift and lower pins. Look through the LHS objective of the microscope. **Do not overtighten!!!** The only way you will know that the limit is reached is by the 'springy' movement of sample - this is the queue to stop tightening;
- If red handles no longer turn, lift the pins up with the 'wall facing' handles and recenter the dial by turning it to no of max turns/2;
- Launch LabView program

Once done, turn off the Keithley voltage source and turn off the white plug that powers the lamp.

CHAPTER 24

# RHUL KLA TENCOR (THICKNESS SENSOR IN CLEAN ROOM)

Used to measure the thickness and width of devices.

1. Load computer using password “‘nanouser’’ → open “alpha set program” → log on with “‘administrator’’;
2. Position sample **make sure pin is raised!**;
3. Double click “‘down arrow’’ to move the pin down. Click “‘up arrow’’ to move pin up for fine adjustments;
4. Turn the knobs to position sample. Use on screen camera to choose position;
5. Set the
  - Scan length (e.g.  $1000\mu\text{m}$ )- the distance the scan carries over;
  - Scan speed ( $50\mu\text{m}/\text{s}$ )- how quickly scan is made;
  - Sampling rate (50Hz)- how fine measurements are made;

Together these dictate the scan time and the resolution.

6. Once ready press start to take scan. **Do not touch table!**;
7. Click levelling → select “‘level 2 zones’” → move the white bars on top graph to area of flat regions for averaging → should create a rectangle like structure on the graph → click “‘OK’”;
8. Use “‘LL’” and “‘RR’” bars to measure width (separation between them) and height (height difference between them);
9. **Double Press “‘UP’”!!** to lift pin → remove the wafer.

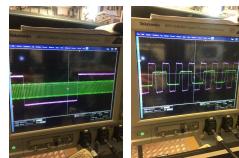


Figure 8: The two images, in which green is the 10 MHz clock signal, and pink is the 10 kHz or 20MHz pulse signal. The picture is stationary, meaning that they are in sync.

CHAPTER 25

## RHUL KEYSIGHT PULSE GENERATOR

- “Utility” → “I/O Interface” → “LAN” → Set IP, DNS and Subnet, the last two as shown in “Network connection details”;
- Type in the IP given to the device in a web browser and get the “VISA TCPIP Connect String”;
- Use this string as the input argument to “VISA OPEN” and you can send commands;
- Chapter 3 of the manual has the remote commands that you can send;
- It has an reference out port from the back. “Utility” → “Reference clock” allows you to choose it as the internal source clock. Now, all the generated pulses will be in sync with this clock → it can be used as a reference clock for other components too.

CHAPTER 26

# RHUL SPA ANRITSU

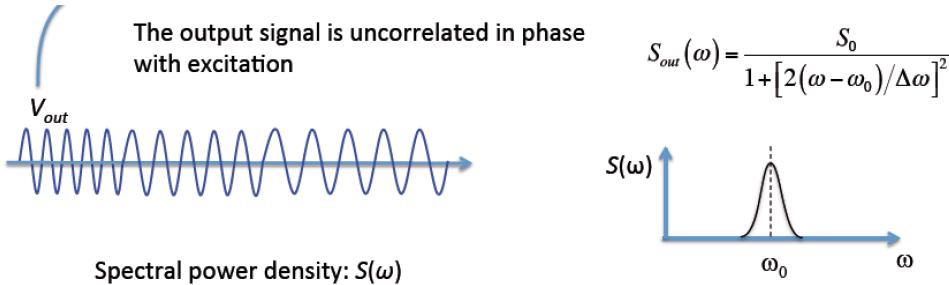
The SPA has important parameters:

- **Span** - the total range of frequencies to analyse;
- **RadioBandwidth (RBW)** - the bandwidth of the filter which operates on the down-shifted signal. If it is large then measurements are quick, since you measure the power over a wide range. If it is small, measurements are accurate, since you average over a small number of frequencies at a single time. Think of it as a window of integration;
- **VideoBandwidth (VBW)** - the bandwidth of the final filter, which can remove noise from the system. The signal that makes it through the RadioBandwidth filter can be analysed with a further filter, which will pick up random fluctuations and average them out;
- **Make sure that TIMESPAN is automatic! Or else the SPA will not use the parameters set.**

In total, the time taken will be (provided that VB is less than RBW):

$$t = \frac{\text{SPAN}}{\text{RBW} \times \text{VB}}.$$

**Spectrum analyser** simply takes the power at different frequencies. There is no phase correlation with the signal that is fed into the system originally



# RHUL VNA ROHDE AND SCHWARTZ

An important parameter is **IF Bandwidth (Resolution Bandwidth, RBA)** which measures what frequency range to capture around every point measured:

~~COVERAGE OF THE MEASUREMENT RECEIVER AND SIGNALS CAN BE MISSED.~~

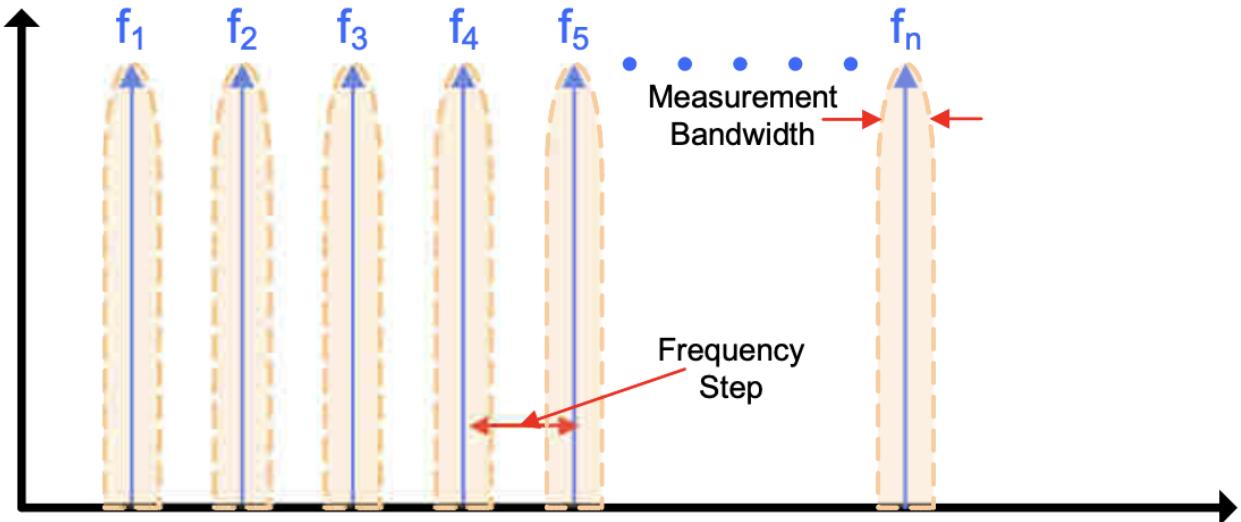


Figure 9: If we take a 4 GHz span starting at 8 GHz and stopping at 12 GHz with **801** measurements points, the resulting frequency step size is **5 MHz**. If then a measurement bandwidth of 10 kHz is chosen, there is a clear gap where we have no coverage of the measurement receiver and signals can be missed.

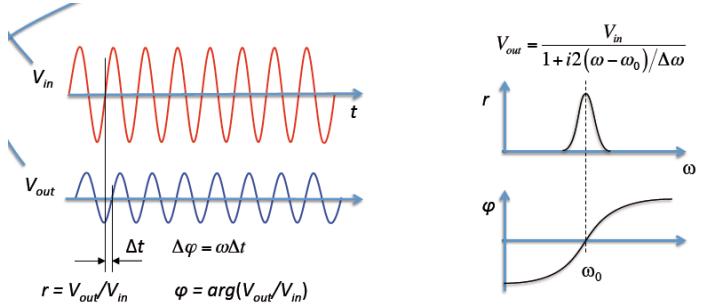
### Make the step smaller than the bandwidth in order to get good overlap

For finer measurement, it makes sense to use a finer bandwidth. If the bandwidth is too small however. 1Hz - 1second per point. 100Hz - 0.01 seconds per point.

- “Sweep” → “sweepTIme”: continuous = sweep, CW = single freq (when we know)
- **Scale** → autoscale
- **Span** → Center 10GHz, span 16 GHz;
- “Power BW AVG” to set power, bandwidth;
- RF ON.

- When first connected via ethernet, run the “rsvna-lv\_2\_42\_0” installer and run the “Set OPC timeout.vi” with 300000ms = 300 seconds or larger in the program, so that the wait time from the VNA to PC is increased.

**VNA** compares the **phase** and **amplitude** of an outgoing signal to the one fed into the system.



# TRIGGER

For two tone measurement set **Trigger from sync**

For Rabi set **Free run**

## 28.1 Correct phase

If the phase is choppy, then do click “Offset-embed” → “Auto-length”.

There is also a program **Trigger-switch.vi** that can do it.

## 28.2 Measure Q factor

To measure q factor of resonator:

- Click “Marker” and select 4 markers;
- Click “Band filter” → “Bandpass reference to max”. make sure it’s set to 3dB;
- Markers will be moved to positions where the peak falls off by 3dB (equivalent to halving) to work our the Q factor

### 28.3 Chopper

The chopper must be connected in the following configuration.

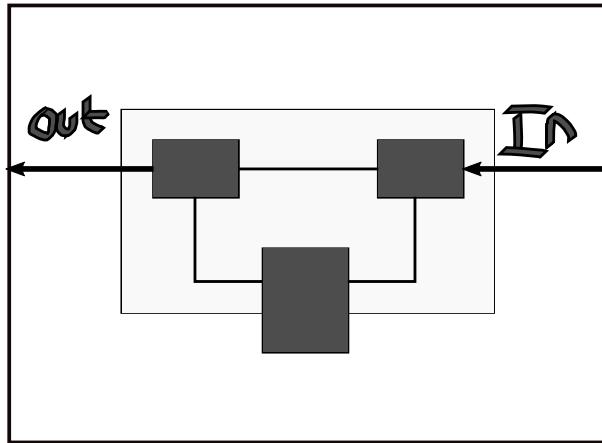


Figure 10: Chooper setup - otherwise there will be bumps in the signal pulses!

CHAPTER 29

# RHUL SMALL LAB PUMP

1. Close the vent valve under the chamber;
2. Connect the orange hose to the rotary pump and push it out of the window to vent the fumes of the rotary pump outside;
3. Flick the pump on → Click “measures” to get the pressure reading;
4. Turn the rotary switch to engage the rotary pump → Turn the black valve on the top → wait 10 minutes to get  $4 \times 10^{-3}$  mBar;
5. Press “start/stop” to start the turbo pump → look for 5W and 963Hz;
6. Wait for  $10^{-6}$  mBar for around 20 minutes - 1 hour;

Then, to vent

1. Close the black valve on top of the rotary pump setup;
2. Click “start/stop” to stop the turbo pump.;
3. Do whatever is required with the chamber → make sure to close the venting valve on the bottom of the chamber;
4. Use the small silver vent on the side of the turbo pump to let some air in and slow it down → ONLY WHEN IT STOPS CAN YOU OPEN THE BLACK VALVE AND START PUMPING THE CHAMBER AGAIN;

CHAPTER 30

# STANTON WEIGHTS IN T125

- Turn on machine from the back;
- Put in dish and turn lever on RHS towards you, so that the orange lights up;
- Rotate the “zero” knob so that the RHS zero on the top scale lines up with the zero on the bottom scale;
- Place sample on weight;
- Using scroll numbers, until the scale moves, indicating that the weight is too heavy → turn the dial back one position and proceed with the next smallest dial;
- Turn the RHS lever to light the green lamp → do the reading:  
**Main scale (g) + digital scale (mg is smallest division) + vernier scale (up to 1mg).**

CHAPTER 31

# WORKING WITH ACIDS

Work on mesh + acids into sink and rinse container with water.

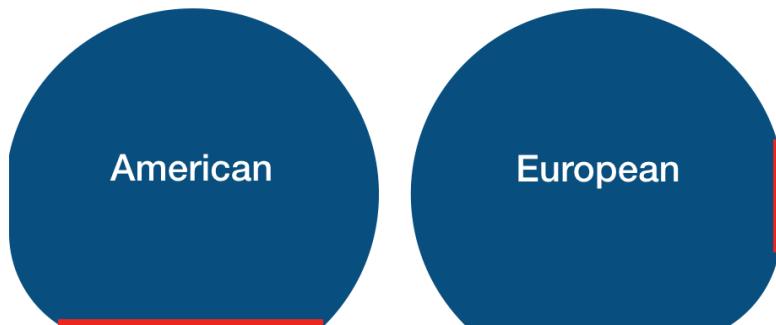
CHAPTER 32

## ELECTROPLATING

1. Fill up bath with button → heat it;
2. Pour in solution into beaker → make sure it stays in place;
3. Attach anode (the stick with the waffle like attachment) to the LHS bar attached to the red wire;
4. Attach the cathode so that the tweezers are not inside the mixture to the RHS blue wired cathode;
5. Chuck in magnet and turn it on to stir;
6. Power supply on and wait;

CHAPTER 33

## WAFERS EUROPEAN AND AMERICAN



When aligning, make the red bit on the bottom for consistency.

Normally during alignment

- Align square by eye;
- Then use exposed edge to align new pattern along crystallographic axes.

CHAPTER 34

## MICROSCOPE NEAR FUME CUPBOARD

- To turn on, hold the green button near the plug for a couple of second.
- Rotate dial on bottom left of base to adjust brightness.
- Turn the bright and dark dial directly under the eyepieces to change the background.
- To take photo, turn on camera and press the LV button. Rotate dial next to AEK-AFL button to adjust the acquisition time of the camera
- Activate by pressing button on block with ‘‘slider’’ image;
- Work with green light when using optical resist;
- In RHUL clean room next to SEM login with **UserName:** olympus-user, **Password:**olympus1 and **THIS COMPUTER Not CC** → “Motic Images” → plug camera in → “Capture”

CHAPTER 35

# INTERFEROMETER

Interferometer is used to evaluate the frequency of an unknown source. This is done by splitting up a beam with a beam splitter, sending two components down different routes with a path difference  $2\Delta L$ . Thus, each time  $2\Delta L = m\lambda \Rightarrow \lambda = 2\Delta L/m$ , there we would have undergone a full interference pattern oscillation, from maxima to minima back to maxima. Thus the distance moved by the mirror,  $\Delta L$ , to complete one period of the interference pattern is used to evaluate the frequency of the source.

1. Set up mirrors, beam splitter, detector. Remember that the mirrors have a focal length - find it by finding where light reflecting off the mirror gets the most intense. This is the distance at which the source of radiation must be placed relative to the ‘guiding’ mirror of the interferometer (which directs the source to the beam splitter);
2. Adjust the ‘guiding’ mirror so that the laser light falls directly in the center of the beam splitter and ‘stationary’ mirror → Adjust the ‘stationary’ mirror so that this reflected right coincides with the incident one on the beam splitter;
3. Adjust the ‘moveable’ mirror so that both reflected paths cross in a single point;
4. Can use a tissue paper to see interference pattern at the output. Put the detector somewhere there.

CHAPTER 36

# CHALMERS DWL 200 OPTICAL LITHOGRAPHY

The pattern is exposed with a laser using a GDS file. It must be booked. LHS computer used to control lithographer, RHS to prepare file.

## 36.1 Loading

1. Switch black switch to open door;
2. Turn on light under the top of the device;
3. Place sample over vacuum hole using “tool 262”. The orientation of the device
  - X-axis away from user;
  - Y-axis from right to left;
4. Switch on vacuum with blue knob → Turn off the light → close the door;

## 36.2 Prepare file on RHS computer

1. Log in → “xconvert” → “new job” → “OK”;
2. In top menu → “add” → “GDS II” → select file → select layer → “create default”;
3. Check parameters → use viewer to see the pattern → “complete task” → “save” → “complete exposure job”.

## 36.3 Focusing (set laser sample distance)

1. LHS → “Hi lithographer” shortcut on desktop → User = “Antonov”, Pass = “19oct2014”;
2. Control system → “center” (to move to center) → check laser has moved → enable “autofocus”;
3. “Focus mode”: for large chips use pneumatic focus, for Small+non reflective chips use optical focus;
4. For thick chips may need to change z-limit → “zMax” → reset “zLimit”;
5. Press “Autofocus” (down arrow) to focus;

6. Press “live” + adjust light to get a visual picture on the central monitor;
7. Typical focusing values: “Piezzo” = 36256, “Autofocus” = enable, “zMax” = 2000

### 36.4 Global alignment

Need to align the wafer to remove rotation and make markers horizontal.

- Find “global alignment tab”;
- Acquire P1 → chose first point by clicking on live image in camera screen;
- Move to new point → acquire P2 → “Save and go to 0-0” → sample is now aligned;
- **Iterate if required.** Can use “micro” to set accurately and “Freeze” to avoid fluctuating focus **but remember to turn off!**

### 36.5 Centering

Perform centering and define markers. Use move to position for direct movement to specific points.

1. “Tools” → “center square” ( $\oplus$ ) to find center of wafer/chip. Draw a square with the marker in the centre and **click scroller button wheel** → enter coordinates of point e.g. 2500 5000 and move around chip to make sure others move into placed;
2. If this fail, manually define a coordinate for centering - click on center of required shape. → “set coordinates”

### 36.6 Expose

1. “Template” → “exposure job” → clone the job that is there;
2. “Designs” → select your design and drag it to the array;
3. Set parameters in “settings/processing”;
4. “Execute”.

File → “logout” out of program on LHS computer and logout of RHS computer.

CHAPTER 37

# CHALMERS SPUTTERING DEPOSITION

## FHR

- Login with “ctrl-l”;
- Vent “c1” → choose tray according to what will be deposited → load sample and slide tray in → “evacuate c1”;

There are 12 program options. **Always press reset before using:**

- Auto 6 - run deposition for 1-6 positions;
- Auto 7 - for cleaning sample;
- Auto 8 - for flushing gas before sputtering;
- Auto 11 - sample loading → Enter position number under “#position”;
- Auto 12 - unload sample from “position” entered in “#position”.

**Stop button turns green once done!**

1. Auto 8 → Load → N2 flush → start → wait 8 min;
2. Auto 11 → “reset” → expand with “arrow” and enter “position” → “start” and sample moves;
3. AutoX → load file → set variable e.g. sputtering time → “start” deposition occurs;
4. Standby c3 → auto12 → reset → choose “position” to unload → “start” (automatic venting occurs) unload.
5. **Evacuate C1 before leaving.**

CHAPTER 38

# CHALMERS PLASMA ETCH

Machine is located next to three transparent “MC2 tiles” in the floor.

- Go to cupboard behind the main machine, and turn on the required valves;
- Go onto screen → Press “stop” → “Vent” → Enter a name for the process (not very important);
- Click “process” → “Recipe” → “load” the correct recipe and overwrite→ click and “edit” process to change parameters;
- Click “run” → two stages will occur, first the pumping of the main chamber and then the etching with the selected plasma.
- While pumping is occurring: Turn on camera switch → turn on camera monitor → turn on utility (from the back);
- Then tune the interferometer. Interferometer simply measure the interference between parts of the laser light, part of which reflects off the Palladium surface (not etched) and part of which reflects off the etched surface → **LASER LIGHT MUST BE PLACED ON THE EDGE OF THE THING THAT WILL BE ETCHED AND WHAT WILL REMAIN**. Every time the distance

$$d = \frac{\lambda}{2},$$

the interference pattern will repeat, where  $\lambda$  is the frequency of the laser light. Thus we count the number of interference periods to get the thickness.

To do so, put laser using the knobs onto wafer (readingA) and metal (readingB). Read off the voltage reading on the unit, tuning offset and sensitivity to get best response. Then position laser to get (responseA + responseB)/2;

**MAKE SURE THAT THE READING ON THE UNIT IS AROUND 5 - OTHERWISE WHEN OSCILLATIONS START THE READING COULD GO OUT OF RANGE!**

- When etching process starts, click “interferogram” button to load the interferogram;
- Once done, click “puase button to terminate process”;
- Once unloaded → “stop” → “evacuate” → unload → “stop” → “vent”;

- If you want another process straight after, then **pump straight away!** since it automatically starts venting!

If special gasses where used, chamber must be cleaned. Close all Chlorine taps behind machine → evacuate and run “Clean Chamber 1 Chlorine” recipe.

CHAPTER 39

## CHALMERS PLASMA CLEAN

1. Utilities → vent → load;
2. Utilities → pump → **hold down by hand!**;
3. Process → common → choose process → run;
4. Vent → unload → pump.

CHAPTER 40

## CHALMERS RESIST STATION

Do not handle stuff over wafers or open cases Place lids face down! Do not touch sides or bottom of resist bottles with pipette!

1. Set temp on oven with dials (hold set and use arrows);
2. **Cut out cone from paper** → place stage;
3. E → select program → E;
4. Double E to run;
5. Clean with acetone;
6. **Clean pipette before use + keep it pointed down.**

Write down time you set to bake.

Clean chip with gas!!

CHAPTER 41

## CHALMERS JETFIRST ANNEALER

1. Turn on machine;
2. Turn on computer;
3. Load sample but **do not cover central sensor!**

4. Load “JetFirst” → “PIMS” → “Processing” → choose “London420” recipe → Download → process → “start”.

CHAPTER 42

# CHALMERS SCRIBER

## 42.1 Create holder

- Get the two hoops and the sheet of adhesive plastics. Place hoops so ‘‘up’’ are facing upwards → place sheet adhesive side up and clamp down;
- Stick on sample → go to station;

## 42.2 Machine

- Turn on exhaust by turning knob on the tube → turn on machine → turn on computer and let it calibrate;
- Movement with arrows on left and right sides;
- **Calibrate scribe tool:** Move microscope to position → press ‘‘drop scribe tool’’ button → turn screw on top of scribe until ‘‘tool ON’’ in NW side of screen goes to ‘‘tool OFF’’ → rotate 1/4 clockwise after that;
- **Lateral adjustment** to make sure scribe coincides with the optical microscope position → ‘‘scribe once’’ to made a line → turn black wheel on RHS of scribe to position line on top of the line that is scribed;
- **Put on wheel** → raise the holder with screw → place wheel text facing out → adjust wheel elevation so that it barely rolls on the surface;
- Put red marker on surface → roll wheel and make sure that two lines are made at the correct separation;

## 42.3 Sample

- Rough rotation calibration with arrows;
- **Fine calibration:** click ‘‘eye icon’’ → select ‘‘image pattern’’ → click on image and ‘‘erase’’ → click blank square were image was → click ‘‘red button’’ and drag square to select the pattern to use → right click ‘‘center channel’’ → click ‘‘eye icon’’ → ‘‘edge vision’’ → click ‘‘center channel button’’ → ‘‘theta 2’’ to perform rotation;

#### 42.4 Peck mode

**Front** is towards the room, **rear** is closer to the wall.

- Raise the stopping hook;
- Position microscope → select “peck” in drop down menu and click “peck mode button”  
→ select whether to do it towards front or rear - the machine will make the peck approximately  $1\mu\text{m}$  above or below the current microscope position;
- Perform peck;
- Then select where cleaving with the wheel will be done towards and break;

Turn off exhaust → turn off machine → shut down computer.

CHAPTER 43

# CHALMERS ELLIPSOMETER

1. Switch on with plug at the bottom → turn on lamp with button that is covered with a plastic cover;
2. Place sample on the stage and ensure that light falls on middle;
3. Load program on computer → go to “hardware” window and click “move” in the menu bar → turn dials so that the cross moves to the centre illuminating as much as possible. Use . and , for vertical movement;
4. Go to “acquire data” → “set angle” → set to 70;
5. “Acquire data” → “spectroscopy” to take the data;

## 43.1 Modelling

- Build up layer by layer by “adding layer” and choosing file with the material and setting “thickness”;
- For unknown material use the “CAUCHY” file and set approximate refractive index in parameter slot “A\_n”;
- Go to “data” window and click “generate data” – check its good;
- “Manual run” → click on the thickness box in top window and scroll with middle mouse button to align the generated and measured spectra;
- Tick the “thickness” and box other parameters you want to fit (e.g. energy, cauchy parameters → click “model”);

This extracts the best thickness fit and refractive index;

CHAPTER 44

# CHALMERS OPTICAL 213 LAMP

Follow the manual for startup of lamp. Power “on” → when “Ready” is shown press “CP” → when “start” is shown press “start”

## 44.1 Loading mask

1. Get the correct chuck and attach it to the vacuum tube. Pull on red screw to release the tube.
2. Click “change mask” → “enter” to turn off the vacuum;
3. Position mask in the check → “enter” to turn vacuum on → slide the chuck into machine;

## 44.2 Loading program

- “Select program” → up and down arrows to select “soft”, “loVac” etc → “select program” to stop selection. Soft, Hard, LoVac, Vac are in order of increasing lithography accuracy (from  $3\mu m$  to  $500nm$ );
- “Edit program” → change exposure time and working distance (typically  $20\mu m$ ), 10 sec pre vacuum → “edit program” to set.
- **MAKE SURE THAT FLOOD IS OFF!!** Or exposure will begin straight after loading;

## 44.3 Loading samples

1. Press “load” → put sample on plate → “Enter” to turn on vacuum → slide in → “Enter” to raise the bar;
2. WEC performed (bringing plate to the mask);

## 44.4 Aligning

By this stage we should be in alignment mode. Choose “split field option”, separate the objectives by turning handles on side of microscope, fine focus just above the lenses. Intensity also above lenses. Rotate microscope with knob on the top.

1. Turn dial “TSA”;

2. Use arrows to move to first marker → “Set preference” to remember position;
3. Move to second marker → “Scan” to move back to first position;
4. Turn X-Y dials to center the marker;
5. Press “scan” → move to second marker → turn Theta dial so that pattern shift halfway to correct position → “scan” to move back to first marker;
6. Repeat above steps;
7. Once alignment looks good enough press “Alignment check” to bring sample close to mask → change magnification → **perform check!! BUT NO MOVEMENT** → press “Alignment check” to move again.
8. **PRESS EXPOSURE TO EXPOSE;**

Automatic unloading. “Change mask” → “enter” → unload → “TSA” off.

# CHALMERS FILE PREPARATION

## 45.1 GDS file

This next step is designed for all files. One needs to convert it to GDS

1. “Open” “Layout editor” program;
2. Load the dxf file from above;
3. Save as GDSII;
4. Connect to MC2 sever (has the name 003 in it) → go to required folder and drop so that it is in the system.

## 45.2 GDS to GPF

One needs to convert GDS to GPF in order for it to be read by the EBG500.

1. Log onto ‘‘server005’’ from Terminal → type ‘‘Beamer’’ and run → load a premade pattern;
2. There should be three blocks. Double click on each block → check parameters → ‘‘OK’’ → click ‘‘run’’ button.
3. Repeat for all three blocks.

## 45.3 Making cjob

Cjob is required by EBL systems, and this takes a bit more work. To begin with, one needs to have access to GDS II or GPF file created above.

1. Go to server → Type in "cjob" to launch program and begin creating the EBL file.
2. Create substrate Drag substrate box → Select type of substrate and set its size;
3. Exposure parameters Drag exposure box to substrate box → Give name → Give accelerating voltage → Pre height measurement? (whether to measure the height from eGUN or not) → Tick "Fixed global mark" and enter coordinates of global marks, their type;
4. Layout parameters Drag layout box → Choose the grid by selecting x and y units. Choose the step between the grids. (The program will find the center of the wafer with the global marks. From (0,0) a symmetrical grid will be drawn out with defined parameters);

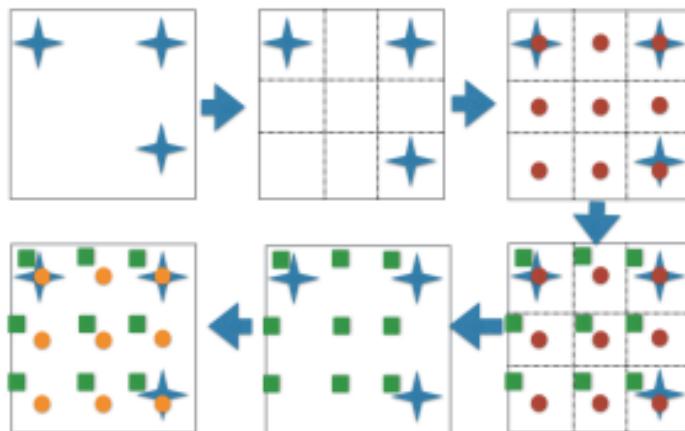
5. **Pattern parameters** Drag pattern box → Load file that will be copied to each grid → Define the local marker positions. (The program will store the location of these markers relative to the centre of each grid. When running, the marks will be found, center of each grid found from relative shift, and the pattern centered on the point found); → Choose Dose to apply (from data sheets) → Choose current to deliver dose **MUST BE GIVE A FREQUENCY ;100MHZ;**
6. Export → choose "branch" to export → export job. File can now be loaded into EBL.

#### 45.4 How pattern is made

1. Define global markers and size of substrate;
2. From global markers, program draws a grid to create number of cells chosen. Wafer size determines grid size. Global markers determine grid position;
3. Center of each grid is treated at the origin (0,0). When defining local markers, they count off from this origin.

Then, in the SEM the markers are used to

1. Find global markers to determine grid location;
2. Move to each grid and find local marker → from the local marker, find the center of each grid.



CHAPTER 46

# CHALMERS ELECTRON BEAM LITHROGRAPHER RAITH

Big machine which operates in a Linux environment. Make sure that files of the correct format are prepared in .gpf format.

## 46.1 Loading

Load the sample onto the holder tray. **Take extra caution when doing this - sapphire crystals are very expansive.**

1. Get holder No.1 → slide onto the metal tray → Push lever on the side and turn to fix the sample;
2. Load the sample - **The orientation is very important! X runs from Faraday cup to bottom of tray - Y runs from left to right;**
3. Name of sample position = Holder No + Position e.g. 23;

## 46.2 Aligning

Move the sample to microscope to fix rotation and height for each sample.

1. Slide tray onto microscope → Fix with lever → Focus with dial on barrel;
2. Remove tilt with “lever”. Slide it in and push from/away to rotate. Get accuracy of  $\pm 0.2^\circ$ ;
3. Turn “Vistec” on → Adjust height in 3 location using “thumbscrews” → **Squeeze middle springs after each adjustment!**;
4. Go to Faraday cup → Click  $X_0, Y_0$  to set this as origin → go to global markers (ones defined in design) → write down coordinates → on computer click # → click “grab position” to store coordinates;
5. Click “lock vent” → after hissing sounds load tray into **correspondingly numbered slot!** → “lock vacuum”;

### 46.3 Computer

Should be logged onto system by now and have terminal and main program opened. The cjob file structure is given in another chapter.

1. “EBG500” → open “csys” (vacuum) → open “csem”;
2. Load terminal;
3. Click “load pattern” → choose pattern that was created and exported in “cjob”;
4. Click “load current” → choose current set in the cjob file;
5. Click # → select file → in position (which should have been grabbed or enter manually) add “-f” to signify that coordinates of global marker are relative to Faraday cup;
6. Check “No unload” box;
7. Holder = TrayNo Position No e.g. 31;
8. “Submit”;
9. Press arrow to load tray.

EBL now knows where to go when starting job.

### 46.4 Alignment inside SEM

Utilise the following commands

#### 46.4.1 Manual

Define the three global markers ourselves. The coordinates of the first one have been captured above. For the other markers, calculate the rough positions of the other markers and then use “mvm” command to get accurate coordinates.

Type in terminal

```
SETWFR “x1Stage”,“y1Stage” “x1Design”,“y1Design” -t “markerType” -m “x2Design”,“y2Design”
“x3Design”,“y3Design”,
```

which should find the markers, turn the stage and output the observed X and Y coordinates of each of the three markers.

Convert these X and Y into microns → go to processes → “edit process” → type in the parameters X1,Y1 X2,Y2 X3,Y3→ “submit”.

Table 1: Remove “/r” to move absolute. Type “-h” for help.

Command	
mcur	move to Faraday cup and measure current
mvm	locate marker in local area
mvm /r “x”, “y” “markerType”	Move relative “x” and “y” and locate marker of “markerType”
mpos /r “x”, “y”	move relative from current position
marker -r	Show all defined marker types
marker -a “name” “shape”	create new marker
“pos/neg” “SizeX”, “SizeY”	
marker -l	load new marker
tpos -a “name” “markerType”	save stage coordinate
tpos -uh “name”	update “name” with current position
tpos -u “name”	move to “name” and reupdate position
pmhv	SEM window
semon	control brightness
pmgm height	turn beam on
	measure height

#### 46.4.2 Automatic

Only the first global marker needs to be found. The coordinate should already by in processes e.g. “-f 50123,454354”. In terminal

```
SETWFR “x1Stage”, “y1Stage” “x1Design”, “y1Design” -t “markerType”
```

so now the SEM knows the real position of the global marker.

#### 46.5 Run and unload

1. To run, drag black line over the process created;
2. Monitor with ‘‘cpro’’;
3. Unload by pressing ‘‘black arrow’’ → ‘‘vent lock’’ → unload tray;
4. REPLACE TRAY, TIGHTEN SCREWS, LOGOUT SYSTEM, LOCK VACUUM

CHAPTER 47

# CHALMERS AVAC DEPOSITION

1. Press red vent button;
2. Load sample onto comb;
3. **Press vent button again** to shut off N<sub>2</sub> gas flow → press “shutter”;
4. Load tray and tighten with alan key;
5. Press “shutter” to replace shutter;
6. Lock door → “vent” → **release door handle** → wait 30 min to  $5 \times 10^{-6}$ ;
7. On numerical screen → “Xtal” to check crystal usage → “Program” → go to film → enter the correct number → check material values with arrows → click “program” again;
8. Click one of the 4 gun positions;
9. Turn red handle on bottom so that its horizontal to turn on high voltage → turn key on top;
10. Click “green” button on remote control → ramp up current dial → tune XY beam configuration so that beam hits and sweeps center of crucible. Typical current less than 1A;
11. Check deposition monitor is at  $\approx 1A/s$  → **click “zero” on monitor and press “yellow” shutter button**;
12. Once done → “shutter button” → tune current all the way down → sweep XY to zero” → turn key → **turn red lock**;
13. Wait 5 minutes → vent → unload → pump.

CHAPTER 48

# CHALMERS EVAPORATION LESKER

Right at the entrance of the laboratory. **Touch screen with pen.**

1. Put spike under the comb holder → slide the samples in;
2. Start “LL vent” → “OK” sign given by machine;
3. Take lid off → put tripod with sample on symmetrically → place lid on side of device;
4. “LL pump” → “OK” press;
5. For better vacuum press “sample pump”;
6. “Select recipe” → “RNiGeAu” → “edit process” to set parameters → “run process;”
7. “SQS214” to monitor process parameters during evaporation. **Load from the KJL window;**
8. To abort process **press green section of execution window and click abort;**
9. **To skip step press white section of execution window and click skip step;**
10. Start “LL vent” → remove wafer plate → replace lid → “LL pump.”;

CHAPTER 49

# CHALMERS LOGITECH POLISHER

Station is used for thinning and polishing wafers. It is located in the room leading out the the corridor that goes along the clean room. **Put on overshoes and gloves.**

## 49.1 Sticking wafer to glass plates

1. Clean small circular disk with ‘‘EcoClean’’;
2. Put samples on glass and place on heater at  $50^{\circ}C$  → swear wax on sides of samples to stick it on.

## 49.2 Prepare machine

1. Turn on blue vent above machine;
2. Place large glass disk on machine;
3. Prepare ‘‘ $Al_2O_3, 9\mu m$  100ml of powder for 750 ml of water’’ in barrel. **Mix together and scrape bottom with screwdriver;**
4. Put barrel with liquid in holder → open the lid slightly → attach the dropper (looks like a half pipe with a wire sticking out) and screw it in.;
5. Attach plate wiper on the side;
6. Cover disk with **distilled water** → then start dropping the grinding liquid **DISK MUST ALWAYS BE WET TO AVOID DAMAGE;**
7. Turn on ‘‘Green Switch’’ button to activate the machine → ‘‘options’’ → ‘‘lap’’.;
8. To begin calibrating get the small thickness sensor and place it on the flat graphite tablet → attach cable to machine from sensor → Click ‘‘setup’’ and you will see a scale from -10 to 10 that measures the concave (edge of mirror is higher) or convex (edge of mirror is lower) of the mirror. **SET TO ZERO** since the graphite plate is absolutely flat. If the reading is close to  $\pm 10$  then read manual oh how to calibrate;
9. Switch on ‘‘abrasive autofeed’’ so the barrel begins rotating;

10. Grab Fork holder and place it on one of the rods. Put the calibrated sensor into it → put weight ring on top, so that the rollers are free to move. May want to change to shorter cable.
11. Then place glass grinder with its holder onto other rod and add a weight on top → start up the machine and monitor the concave/convex monitor → move the grinder to the middle if the mirror is too concave, or to the edge if it is too convex → spin at 20rpm until the monitor is near zero;
12. Wait 5 minutes

Remove grinder and wash in ultrasound. The glass mirror is now ready to grind.

### 49.3 Thinning wafer

1. Run “system check” which will move the rods;
2. Measure wafer thickness by using pump device. Measure on glass → set to zero → measure on plate.  
**Drop the pin very carefully!;**
3. Place the wafer on the big holder → attach vacuum pipe → squeeze the big holder spring, so that the sample is lower than the outer edges of the device → transfer onto disk and position;
4. Reset the thickness and start up the machine. Thickness is evaluated by calculating the spring extension inside the device as the wafer is thinned;
5. Stop machine → rinse wafer in water → clean the grinder and thickness monitor with ultrasound, rest with water → **remove solution bottle from top!;**

### 49.4 Polishing

1. Make sure all components are cleaned from the  $9\mu m$  solution that would destroy the polish → take the “polish disk” and drain it with water;
2. Attach the small thickness sensor → attach the doughnut shape metal to the other side → spin and spray on the polish solution until disk is evenly coated;
3. Load the sample onto the big holder → turn on vacuum → squeeze it and transfer to plate;
4. Start rotating → every 40 seconds squeeze more liquid;
5. Once done, immediately remove holder → turn off vacuum and wash to remove the chemical creating the polish;

**Wash everything in water → turn off vent.**

To remove from glass Place in 150 °C EcoClean → EcoClean → Acetone → IPA.

CHAPTER 50

# SCRATCHING DEVICE MS100

Used to make scratches on chips. To break the chips, use the metal bar in one of the labs.

## 50.1 With pen

- Put cloth on sample. Put metal bar on top for guidance.
- Use gold pen to make a scratch.
- Align edge of wafer with the metal bar edge → put cloth on top → push next to edge with something plastic;

## 50.2 With device

- Load computer open uEye demo
- Press the camera button with the green arrow. Connect to the camera via USB.
- Place sample on tray. Use big lever for movement. Use black dial to lift the platform. Use little lever to adjust rotation.
- Swipe back and forth to check alignment. Once happy, turn the dial under the scratcher arm to lower the scratcher.
- Use big lever to move scratcher across surface. A dark line should appear.

Dont forget to turn the computer off!!

## 50.3 Cutting

- Position the chip with the scratch parallel to the edge of the metal bar and on top.
- Cover with a cloth and break.