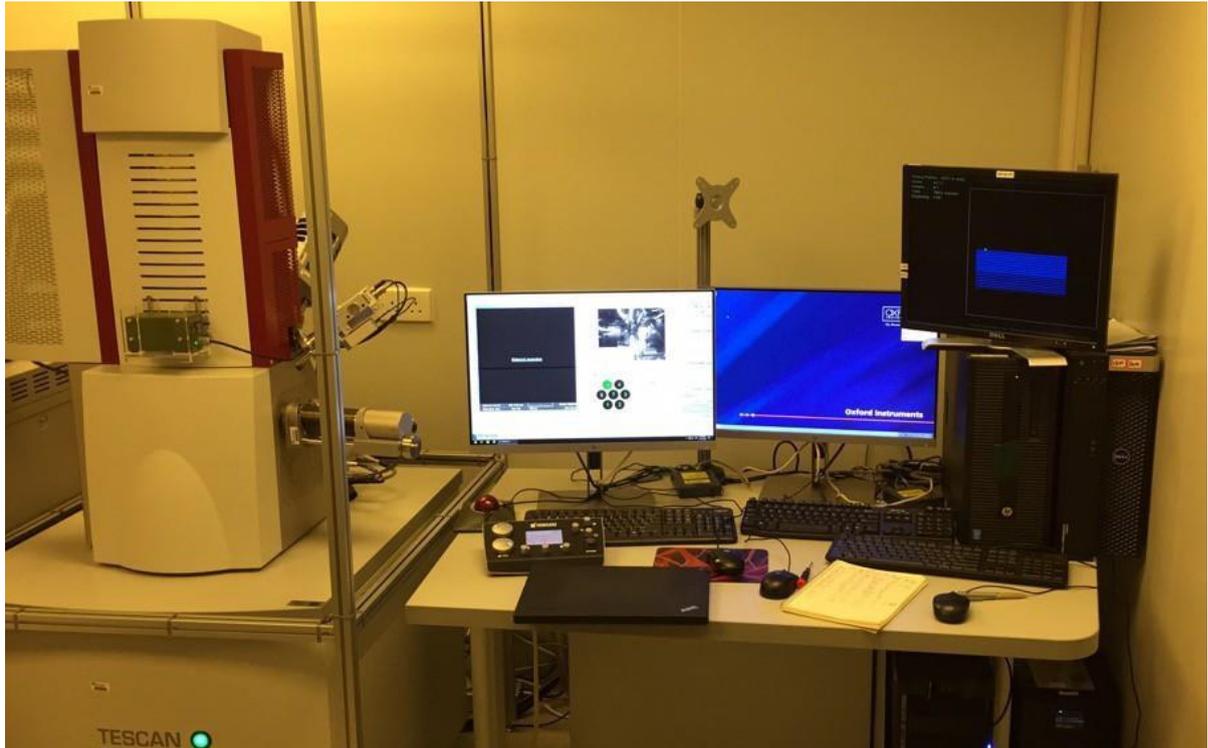


Electron Beam Writing with NPGS SOP

This is a shortened version that focuses mainly on routine operation.

For more detailed instructions, please refer to the user manual "[MAIA3](#)" and [NPGS official website](#).



1. System

1.1 This document provides operating procedures and requirements for electron beam lithography. **Please refer to “MAIA3 Scanning Electron Microscopy” manual for the imaging procedure.**

1.2 System description

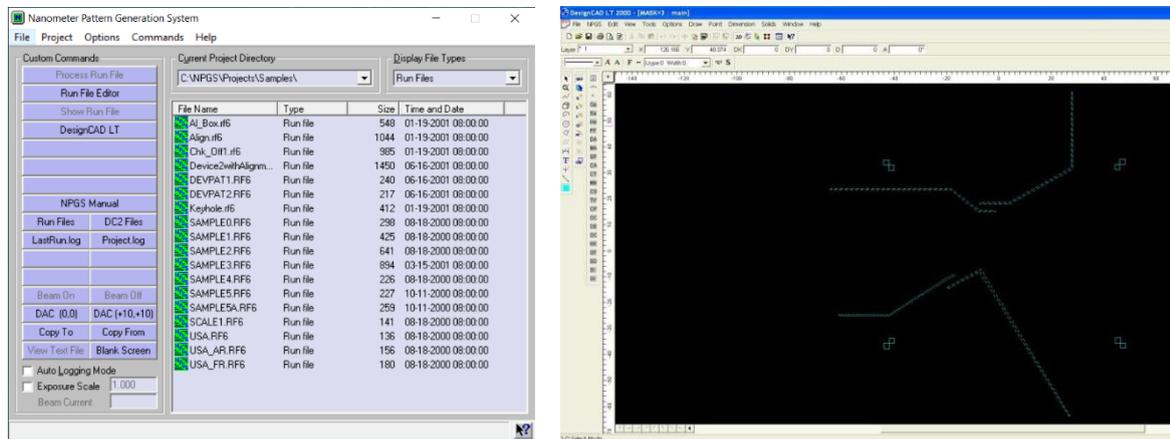
The MAIA3 SEM uses the Nanometer Pattern Generation System for Electron Beam Lithography Writing. An SEM lithography system is a tool which can be used in a wide variety of applications. The basic lithography process allows patterns to be defined on a flat surface. The subsequent processing, such as metal evaporation or etching, will determine the final structure. NPGS is unique in that it provides a very flexible system which is ideally suited to the wide range of activities in basic research and R&D activities.

2. Before starting

- 2.1 You have to operate the SEM expertly and be authorized for SEM usage before electron beam lithography training.
- 2.2 You must go through manual of MAIA3 SEM, manual of Nanometer Pattern Generation System and manual of Design CAD before electron beam writing training.
- 2.3 You must be authorized by Dr. Tang and properly trained by Dr. Tang's group member before operating the system.
- 2.4 No wet, biological, or other contaminating sample allowed inside the chamber. Consult with Dr. Tang if you plan to do put such sample inside the chamber.

3. Software user interface

Two software interfaces are mainly used for electron beam lithography: NPGS (Nanometer Pattern Generation System) and Design CAD.

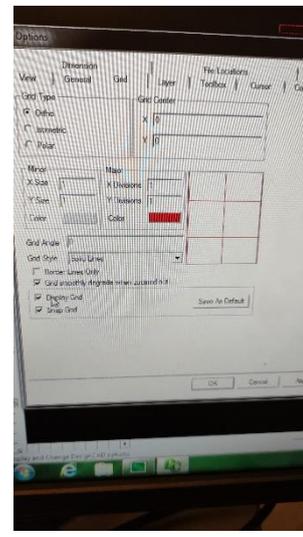
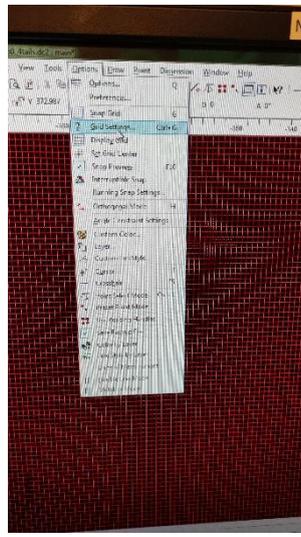
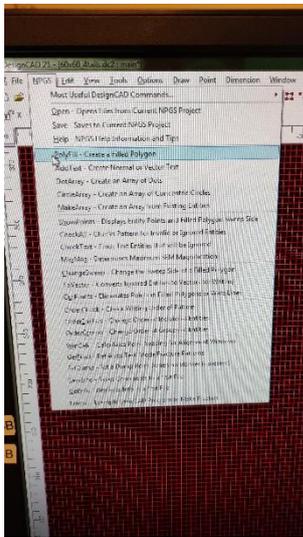


4. Operation instruction

4.1 Preparation

Most widely used electron beam resist is PMMA which can give very high resolution (<10nm). The PMMA 950K A11, A7, A4 and A2 are in stock inside CYM 408 and ready for use. Spin coater and baking hotplate are also located inside CYM 410 fume hoods. For spin condition of PMMA resist please consult <https://kayakuam.com/products/pmma-positive-resists/>. Other electron beam resist such as ZEP, SU-8, and HSQ can also be used inside this system.

Before writing session, the user should pre-design the CAD file with Design CAD in DC2 format. It is recommended to do the CAD design on a personal computer instead of on SEM computer. The installation file can be found by contact with Dr. Tang's group member. Open CAD software, use "PolyFill" function in "NPGS" menu to depict your pattern. You can use the "Grid Setting" function in the "Options" menu to define the Minor XY size and tick "Display Grid" to help you delineate your pattern.



If you aim to acquire a large amount of your pattern in array, you can click the “Array” button in “Draw” menu and set the “Columns” and “Rows” value as you desired:

After finishing your pattern, you can select all of them and click “MaxMag” button in “NPGS” menu and then press “o” on the keyboard to move the centre of your drawing to the origin of coordinates (0,0).

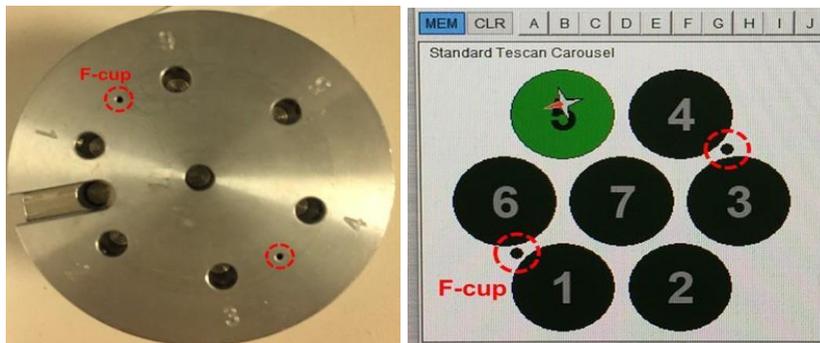
Finally, save your project by clicking the “Save” button in the “NPGS” menu, NOT in the “File” menu!

Turn the five switches from EDX mode to NPGS mode:



4.2 Load sample and current measure

- 4.2.1 Load sample with spring-loaded holder similarly as imaging process. It is helpful to scratch on four corners of your sample for latter focus. **Note that the sample should be placed flat and expose at least one F-cup.**
- 4.2.2 After pumping to high vacuum, turn on beam at 30kV.
- 4.2.3 Image and focus on the edge of F-cup. Move the stage height to ~7.5mm. It is possible to use height greater than 7.5mm, such as 15mm or 20mm if large pattern size is needed without extreme resolution.
- 4.2.4 Move to the centre of F-cup and increase magnification to zoom at the way inside so that the SEM screen is completely black (adjust the magnification to the maximum value) This will ensure all electrons are collected by F-cup. **Note that every time you pump to vacuum to write e-beam, you should test the beam current.**



4.2.5 Read the beam current from external picoammeter when applied different level of beam intensity.

Record the difference as beam current value on logbook and your run file. Adjust the wobbler and stigmator as necessary.



In case the beam current is shown on SEM computer but not on the external picoammeter. Click the “**Sample to external picoammeter**” in the “SEM” menu. It is recommended to use data from external picoammeter instead of internal picoammeter due to higher accuracy and reliability.

In the “Run file editor”, type the Beam Intensity to “configuration parameter” and beam current to “Measured Beam Current”, respectively.

4.2.6 Check and correct the astigmatism at Z height ~7.5mm (for ~200nm resolution).

If your pattern is as large as several hundred microns and there is no need to reach a high resolution, you can lower down the Z distance to 15mm for example to decrease the astigmatism.

Align sample with appropriate X-axis by using align X (or align Y) inside the stage menu. Focus on the corner of your sample, after Z adjust the height to the desired height. Switch the SEM mode to NPGS mode on the software’s window; then the SEM screen will turn out to be “External Scanning”.



Optional: Check NPGS status.

Before moving your sample to the writing place, you may check whether the NPGS is successfully controlling the SEM scan.

Go the NPGS → Commands → Digital Imaging → start a new scan.
If you see image of the same as the SEM, it means the system is correctly connected, otherwise, check your setup and try again.

4.2.7 Move to the area where you want to write your pattern on and adjust the beam intensity, magnification to your designed file. (If in your run file, you enabled digital SEM control, the system will automatically adjust all parameters as you selected in the run file.)

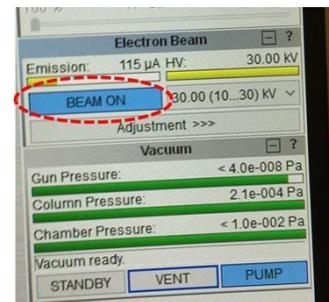
Process run file from NPGS computer, the beam writing will start. An estimated time will show on the screen as well.

Optional: It is recommended to monitoring the beam current on the picoammeter at the start and at the end of the patterning. If the reading changed dramatically, your writing dose might be shifted.

Once the writing is finished, move the stage to F-cup first, and then switch back to the SEM mode on the software.

4.3 Finish

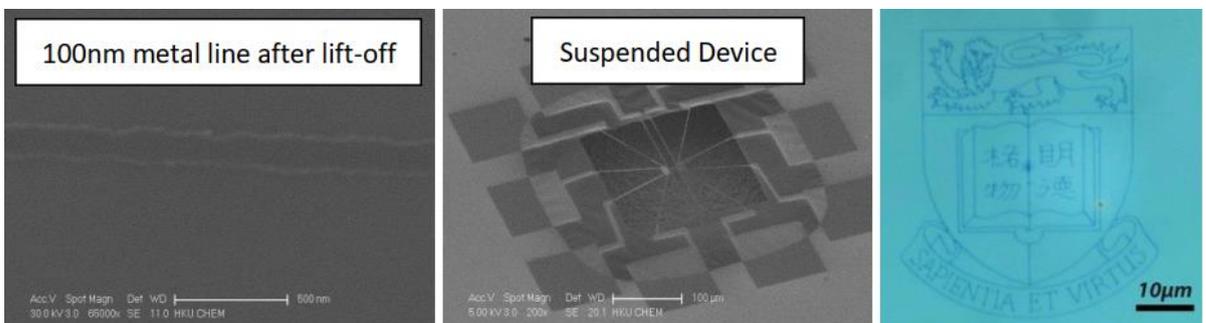
Turn-off Beam by click **beam on**. Home the stage and vent the chamber. Retrieve your sample. Pump system back to vacuum, wait for “**Vacuum ready**” before leaving the room. Turn switches back to EDX mode near the SEM. Record your usage status on Logbook.



(For PMMA sample, there are two ways to develop sample. The most widely used developer is MIBK: IPA 1:3, which is in stock in CYM 408 clean area. For $\sim 0.5\mu\text{m}$ line features, the dose should be $\sim 400\mu\text{C}/\text{cm}^2$. Larger size pattern needs a lower dose, for $10\mu\text{m}$ feature, the dose is $\sim 300\mu\text{C}/\text{cm}^2$ while the small feature will need a significantly higher dose. Check proximity effect for more information

[https://en.wikipedia.org/wiki/Proximity_effect_\(electron_beam_lithography\)](https://en.wikipedia.org/wiki/Proximity_effect_(electron_beam_lithography))

Examples of beam writing:



5. Trouble Shooting

Very blur pattern: The focus maybe far off, auto XY focus mode can be used to correct this. Consult super user for detail.

Pattern does not come out completely or no pattern at all: Make sure the beam is not blanked from SEM side, and the dose is correct.

6. Questions for Examination

1. What is the typical dose for PMMA and SU-8 resist
2. What will happen if you did not flip the five switches from EDX mode to NPGS

mode?

3. I want to pattern SU-8 with ebeam lithography, so I spin coat the sample with SU-8 2015. But my always end up no pattern. What is wrong.
4. I pattern 200nm thick PMMA with dose $400\mu\text{C}/\text{cm}^2$ for $1\mu\text{m}$ PMMA, what dose should I use?
5. I successfully patterned a pattern with $5\mu\text{m}$ features; the dose is $350\mu\text{C}/\text{cm}^2$. But with the same setup, my 400nm feature did not show up. Why?
6. In the run file, there is a centre to centre distance and line spacing. What does it mean?
7. In the design CAD file, what does the colour means? What does the layer mean?

Advanced questions:

7. In many cases, you want to pattern a electrode to on a material for measurement (like graphene flake, nanowire, etc.) In this case, you need to do alignment, how to do alignment?
8. In many cases, you will pattern fine lines with large contact pad for electrical measurement. However, if you use large beam current, the fine feature cannot be resolved, if you use small beam current, it will take over 10 hours to write the big electric contact pad. What you should do?
9. When you choose two beam current to pattern a sample, your pattern is disconnected at the joint location of different beam. What you should do?