GENERAL PROCESS AND OPERATION SPECIFICATION

Tescan MIRA3 Electron Beam Lithography

I. SCOPE

The purpose of this document is to describe requirements and basic operating instructions for the TESCAN MIRA 3, E-Beam Lithography tool. This tool is intended for nano-patterning by electron beam.

II. SAFETY

A. This machine's detailed safety information can be read in the User Manual.
B. Record the tool malfunction, breakage, etc. in the log-sheet and send an email to staff. Never try to fix anything by yourself.

III. APPLICABLE DOCUMENTS, MATERIALS AND REQUIREMENTS

A. For more information about the physical description and operation of the Tescan EBL tool, please request the complete user's manual.

IV. OPERATION

1. Loading the sample
    a) Log into **Mira-TC** software by clicking on MIRA3-TESCAN icon and entering user name and password.
    b) Vent the chamber by clicking on the **VENT** button on the Vacuum Panel and wait to reach "**Venting finished**" status. (**Note**: make sure the stage is at **home** position (X=0; Y=0; Z=40; Rot & Tilt = 0°) before you vent the chamber. If not, click on Home button in stage control panel).
    c) Open the chamber gently and load the sample onto sample holder. **User must have clean gloves on while loading and unloading the sample.**
    d) Gently close the chamber and hold the chamber's door.
    e) Pump the chamber by clicking on the **PUMP** button on the Vacuum Panel and wait to reach "**Vacuum ready**" status.
2. Turning on the electron beam
    a) Move the stage above **gold standard** position.
    b) Open the "**Beam Blanker**" panel in the main SEM menu and select "**Enable beam on acquisition".**
    c) Select **SE** detector in the SEM Detectors & Mixer panel. Make sure the BSE detector is retracted.
    d) Set the exposure parameters including acceleration voltage (**HV**; 30 kV is recommended) and **Beam Index** (BI; less than or equal to 5 is recommended) in Info Panel. (Note: for large patterns where both dimensions are in the range of few tens of microns and resolution is not as critical, use BI 8-10 to reduce the exposure time (higher BI is equivalent to higher beam current)).
    e) Turn the electron beam on by clicking on the **BEAM ON** button on the Electron Beam panel.
    f) Perform focus on gold standard at 50kx by turning WD knob on Control Panel. Once the gold standard is focused, gradually decrease WD&Z in stage control

panel (WD&Z = 15, 10, and then 6.0) and re-perform focus until gold standard is focused at **WD ≅ 6.0.**

3. Electron column alignment
    a) Perform fine focusing at magnifications ≥200kx.
    b) Perform gun centering by automatic procedure. Click on **AUTO GUN CENTERING** on the Electron Beam panel.
    c) Perform Column Centering (Centering the aperture) manually. Click on icon on the toolbar and use control panel knobs (for X and for Y) or the trackball to center the aperture.
    d) Correct Astigmatism (Correcting non-circularity in electron beam). Click on icon on the toolbar and use control panel knobs or the trackball.
    e) Re-Perform focusing.
4. Exposure
    a) Open the DrawBeam panel in the main Tools menu.
    b) Create a new project/open a saved project/ import from GDSII format by clicking on the / / icon.
    c) Click on the icon in the DrawBeam panel to open the DrawBeam Process panel. Enter the suitable Dose(s) and Spacing by double click on **Dose window**. (Note: keep the spacing at minimum possible value;
    (1) Exp pitch should be ≥ 4×DAC resolution (DAC res. depends on view field)
    (2) Exp pitch = spot size × spacing.
    d) Move the stage to the faraday cup. Magnify to 50kx (the entire screen should be black; i.e. all the electrons should be collected by faraday cup). Measure the **beam current** by clicking on icon in the DrawBeam Process panel. The correct value of the beam current will be automatically inserted in the panel.
    e) Move the stage to the edge of the sample and find the scratch you made on sample after spin coating. Click on Define UV and then Align sample to align sample with x and y directions.
    f) Go to the tip of the scratch. Take caution not to expose the sample. Find a tiny particle and try to bring the particle on focus **without changing WD**. In order to do that you need to change Z. Keep changing Z using buttons until you see a clear image of the particle.
    g) Open the **Analysis & Measurement** panel in the main Tools menu (steps 4.4.7-4.4.9 are optional if step 4.4.6 is performed properly).

h) Click on the New Point/line button and place the point (Magnification should be 400kx). Start and stop the burning by clicking on the icon. The burning time is 10-20 seconds.
i) Perform final focusing and astigmatism correction on the spot to achieve an ideal circular spot. Repeat burning and focusing, if necessary.
j) Blank the beam by clicking on the **Single button** on the Info Panel.
k) Move the stage to exposure location by entering new X and/or Y coordinates.
l) Start the exposure by clicking on button in the DrawBeam Process panel. Move the stage and start another exposure, if needed.
m) After exposure is finished, turn the beam off by clicking on the **BEAM ON** button on the Electron Beam panel.

5. Unloading the sample
   a) Move the stage to home location by clicking on **home** button in Stage Control Panel.
   b) Vent the chamber by clicking on the **VENT** button on the Vacuum Panel and wait to reach “**Venting finished**” status.
   c) Open the chamber gently and unload the sample.
   d) Gently close the chamber and hold the chamber’s door.
   e) Pump the chamber by clicking on the **PUMP** button on the Vacuum Panel and wait to reach “**Vacuum ready**” status.
   f) Log off the software. Click on the log off in the main tools menu. You will be asked two question: 1) do you really wish to log off: **Yes** 2) Go to the STANDBY mode: **No**
   g) Fill out the log-sheet

NORMAL OPERATION

SIGNATURES AND REVISION HISTORY

a. Author of this document: Mitchell Roselius
b. Author Title or Role: Student Technician
c. Date: 2/25/2021
d. Revision: Revision a
e. Revision notes: Added: film stress measurement procedure, film roughness measurement procedure, operation warnings (see Safety D-F).

Approvals:

Technical Manager Signature:____

Date: ____

Revision History:

Revision	Author	Date
Original Issue	Manouchehr Teimouri	03/05/2018
Rev A	Mitchell Roselius	2/25/2021

Appendix A – Examples for Writing Circles, Lines, Rings, and Texts

Nano-patterning of Circles

Si Substrate

40nm Cr disk

500 nm

Nanofabrication of an array of 40nm-diameter lifted-off chromium disks with 200nm pitch

Si Substrate

40nm Cr disk

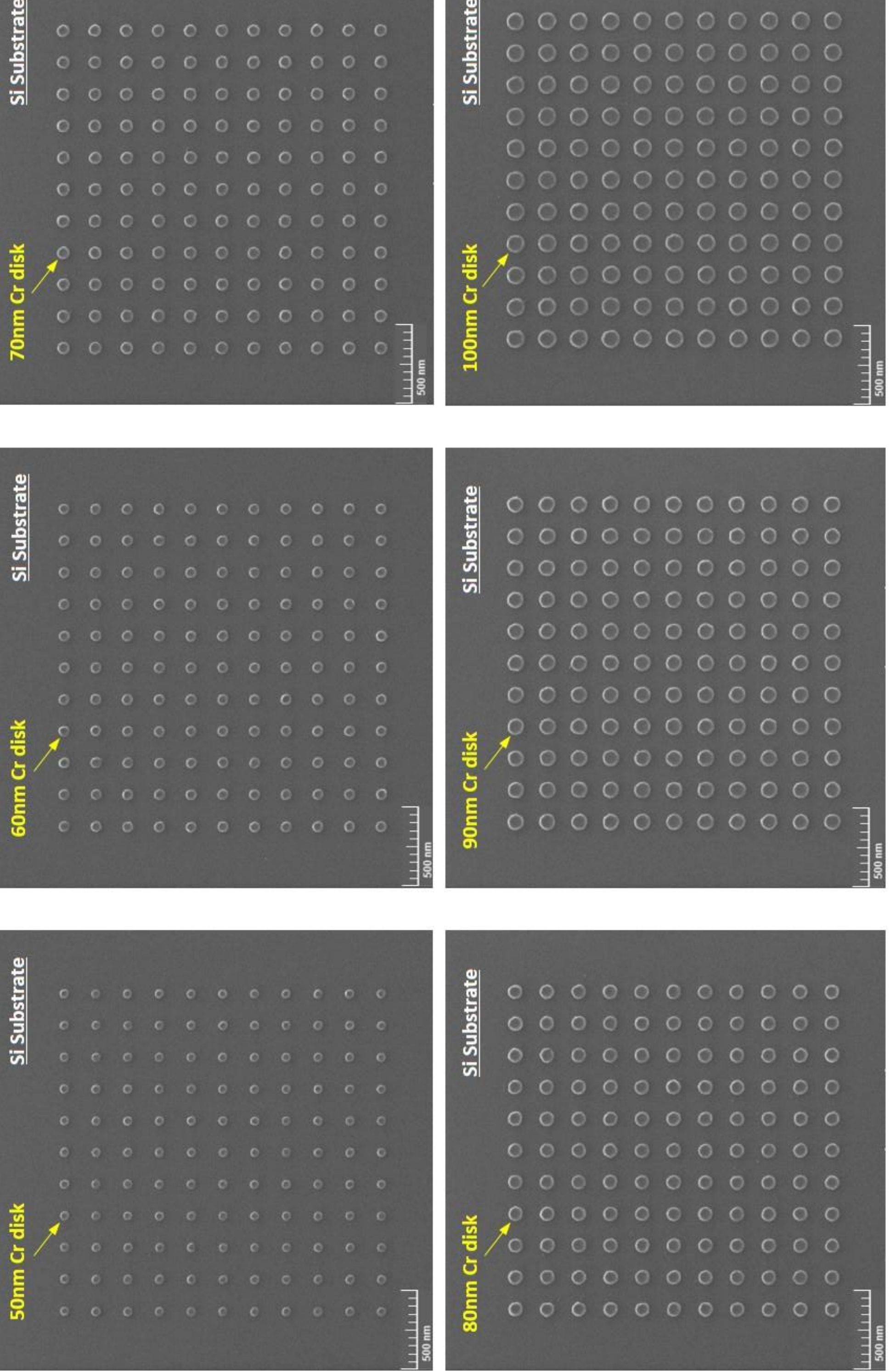
1 µm

Nanofabrication of Texas A&M logo with 40nm-diameter lifted-off chromium disks

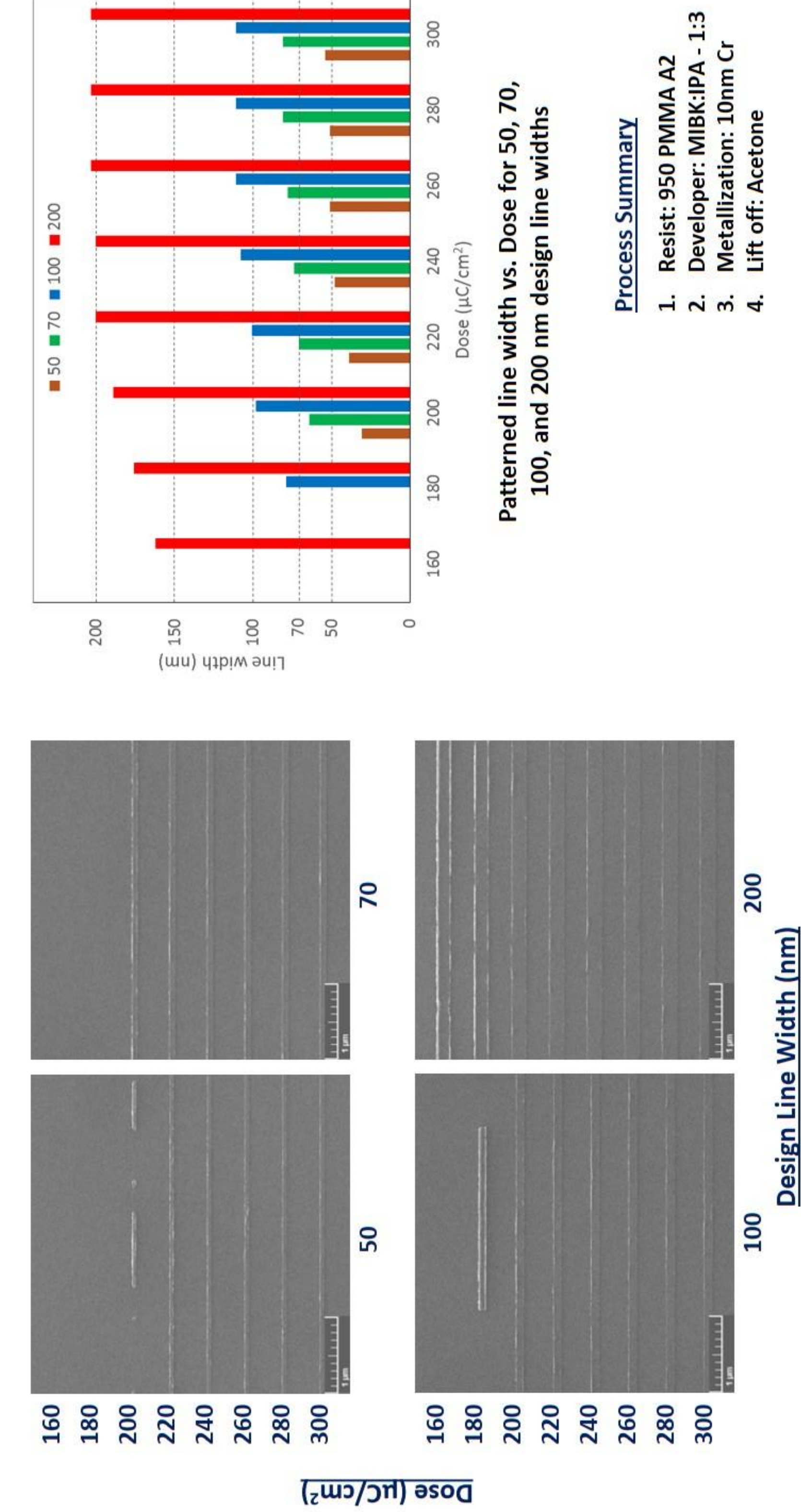
Process Summary

1. Resist: 950 PMMA A2
2. Dose: 350 µC/cm^2
3. Developer: MIBK:IPA - 1:3
4. Metallization: 10nm Cr
5. Lift off: Acetone

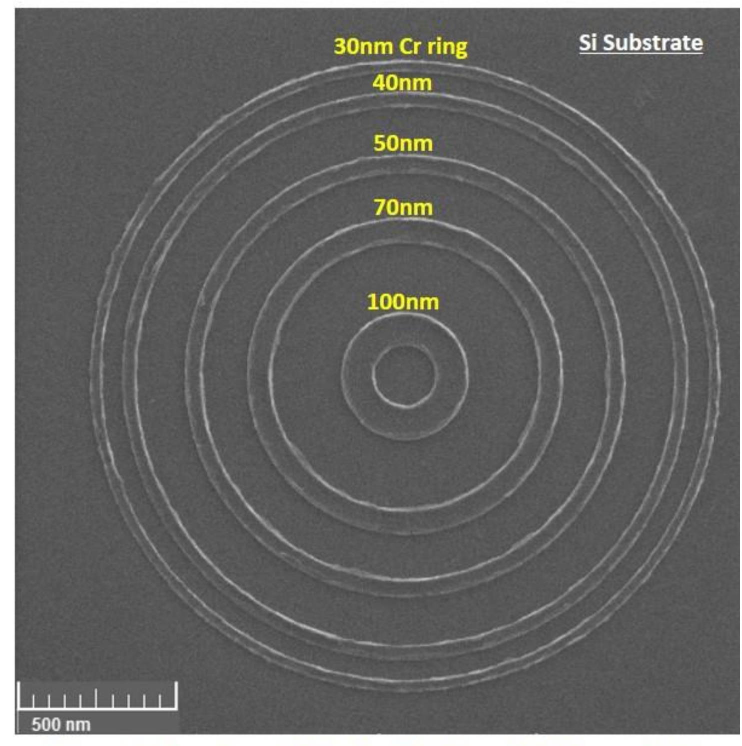
Nano-patterning of Circles



Nanofabrication of an array of 50, 60, and 70-nm (top row ; left to right) and 80, 90, and 100nm-diameter (bottom row ; left to right) lifted-off chromium disks with 200nm pitch


Nano-patterning of Lines – Dose Chart
Dose (µC/cm²)
160
180
200
220
240
260
280
300
50
70
100
200
Design Line Width (nm)
50
70
100
200
Line width (nm)
Dose (µC/cm²)
Patterned line width vs. Dose for 50, 70, 100, and 200 nm design line widths
Process Summary
1. Resist: 950 PMMA A2
2. Developer: MIBK:IPA - 1:3
3. Metallization: 10nm Cr
4. Lift off: Acetone
Note: line load and spacing affect patterned line width

Nano-patterning of Rings

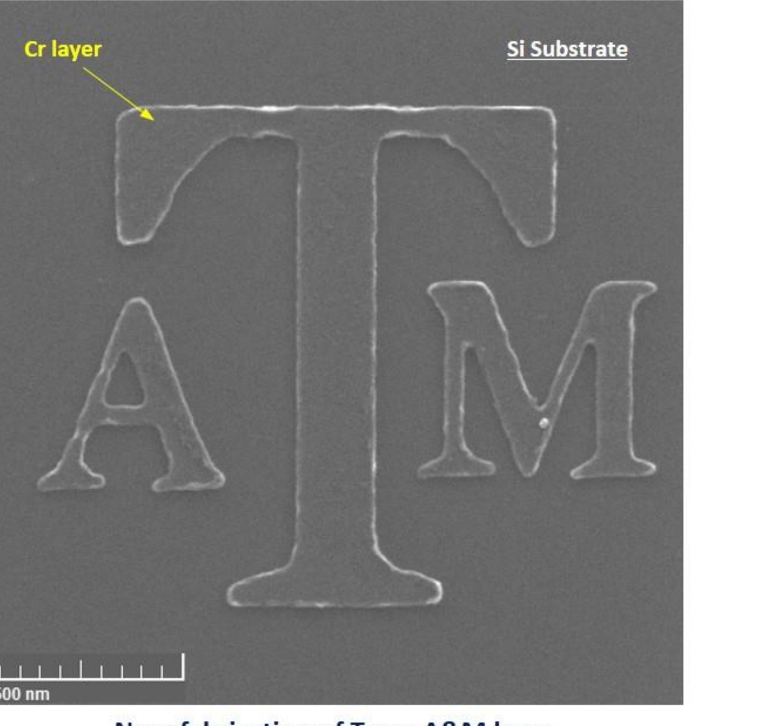


Nanofabrication of 30, 40, 50, 70, and 100nm-width lifted-off chromium rings

Process Summary

1. Resist: 950 PMMA A2
2. Dose: 250 $\mu C/cm^2$
3. Developer: MIBK:IPA - 1:3
4. Metallization: 10nm Cr
5. Lift off: Acetone

Nano-patterning of Text



Nanofabrication of Texas A&M logo
with 15nm-thick lifted off chromium layer

Nanofabrication of Aggiefab
with 15nm-thick lifted off chromium layer

Process Summary

1. Resist: 950 PMMA A2
2. Dose: 325 µC/cm^2
3. Developer: MIBK:IPA - 1:3
4. Metallization: 15nm Cr
5. Lift off: Acetone

Appendix B – PMMA Spin Coating and Developing

PMMA is purchased from Micro Chem

Spin Coating:

Step 1: 500 rpm, 5 seconds, 100 rpm/s

Step 2: 3000 rpm, 45 seconds, 500 rpm/s

Soft baking: 185 C for 90 seconds

Thickness: 950 PMMA A2: ~ 80 nm ; 950 PMMA A4: ~ 240 nm

Developer: 1:3 MIBK:IPA (MIBK: 4-Methyl-2-pentanone; purchased from Sigma Aldrich)

Develop time: gently shaking for 60 seconds

Wash thoroughly with DI Water after develop

Dry with N2.