Electron Beam Lithography in PMMA

Substrate Preparation

1. Clean the substrate by sonicating in IPA solution for 5-10 minutes.
2. Select ramping, spin speed, and timing based on spin coating curve.(Appendix 1)
3. Prebake at 180 degree on hotplate for 90 seconds.

Writing Preparation

1. Load samples on a multiple stage: gold standard, Faraday cup, and a coated substrate.
2. Load multiple stage to the chamber.
3. Turn switch located in the chamber from Alarm (A) to Current (C).
4. Connect Keithley 6485 Picoammeter to Sirion.
5. Pump down the chamber.

Electron Beam Alignment

1. Select accelerating voltage and beam spot size for a desired beam current.
2. Focus on gold standard and adjust WD to 6.5 mm.
3. Adjust stigmation/lens alignment as needed to resolve well defined edges and features on the surface.
4. Acquire an image at magnification of >100,000 and compare it with the attached image in Appendix 2.

DO NOT adjust stigmation once adjustments have been completed!

Electron Beam Current Measurement

1. Move stage to Faraday cup and find 75 micron black aperture hole.
2. Increase magnification to such that the cup can collect entire beam.
3. Press ZCHK on Picoammeter to trigger current measurement.
4. Read current from Picoammeter (30 μm microscope aperture):
    a. 30 kV/Spot1 = ~ 13 pA
    b. 30kV/Spot2 = ~ 22pA
    c. 30 kV/Spot3 = ~ 75 pA
    d. 30 kV/Spot4 = ~ 300 pA
    e. 30 kV/Spot5 = ~1180 pA
5. Allow beam to stabilize itself in the cup for 10 minutes.

Definition on Sample Surface

1. Move stage to top edge of the coated sample and AVOID exposing the entire surface to electron beam.
2. Use Stage/x-align/y-align command to adjust stage rotation.
3. In the Stage submenu, make sure Scan Rotation is set to 0 degrees.

4. Move to the designated area in which you will perform writing. Using Z-height adjustment knob, focus on a particle near the resist surface.
5. For final focus, adjust the working distance using the mouse with fine adjustment.

Hardware Setting for NPGS

1. Connect NPGS digital cable bundle.
2. Switch box setting: **B**, computer monitor setting: **2**, and open SCS communication program from the microscope computer.
3. Set the microscope to “Display” mode using Mag/Device/Display.

Four-Point Focus

1. Locate first corner scratch mark and focus with mouse at magnification ~500x.
2. Initiate NPGS focus point collection **Commands->Direct Stage Control.**
3. Skip rotation correction prompt and proceed to focus point **Acquire New Data.**
4. Acquire first scratch mark X, Y, and WD information by pressing **Space** bar.
5. Proceed to next corner scratch mark, focus on scratch, and repeat step 4 until remaining three corner scratch mark data has been acquired.
6. Once all focus data has been collected, hit **Enter** to save new data.
7. Hit **ESC** to exit the Direct Stage Control program.

Checklist for Communication between NPGS and Microscope

1. Turn on Beam Blanker power supply and position at “**External**”.
2. Use NPGS “Read WD” command to read WD from NPGS computer.
3. Use NPGS “Set Blanker” command to turn beam on/off.
4. Set SEM microscope to external X-Y (select Scan/External x-y on Sirion).
5. Take “Digital Imaging LoRes 1000x” to confirm imaging communication.
6. Run “Calibrate DACs” command to set correct Beam Blanker voltages.
7. Use NPGS “DAC +3.6, +5” command to set DAC board X, Y voltages.

E-Beam Writing

1. Select Run file from NPGS software.
2. Adjust center to center distance and exposure time (See Appendices 5 and 6 for line dose and area dose, respectively).
3. Following the settings shown in Appendix 3, select NPGS Command/Process Run File/Time Test Mode to run a time test experiment.
4. Change Advanced mode settings to ‘Non-Stop Writing: Yes’ to process run file Appendix 4).

Post-Writing Checklist

1. Turn off the e-beam immediately after writing process.
2. Switch NPGS digital cable bundle back to EDX.

3. Turn off Beam Blanker power supply.
4. Change SEM back to “Videoprint” mode.
5. Change SEM back to “Full Frame” mode.
6. Reset beam voltage/spot size back to 5kV/Spot3.
7. Vent the chamber and unload sample.
8. Switch stage alarm from “**C**” to “**A**” setting.
9. Pump down the chamber.
10. Disconnect Picoammeter from SEM and return to shelf.

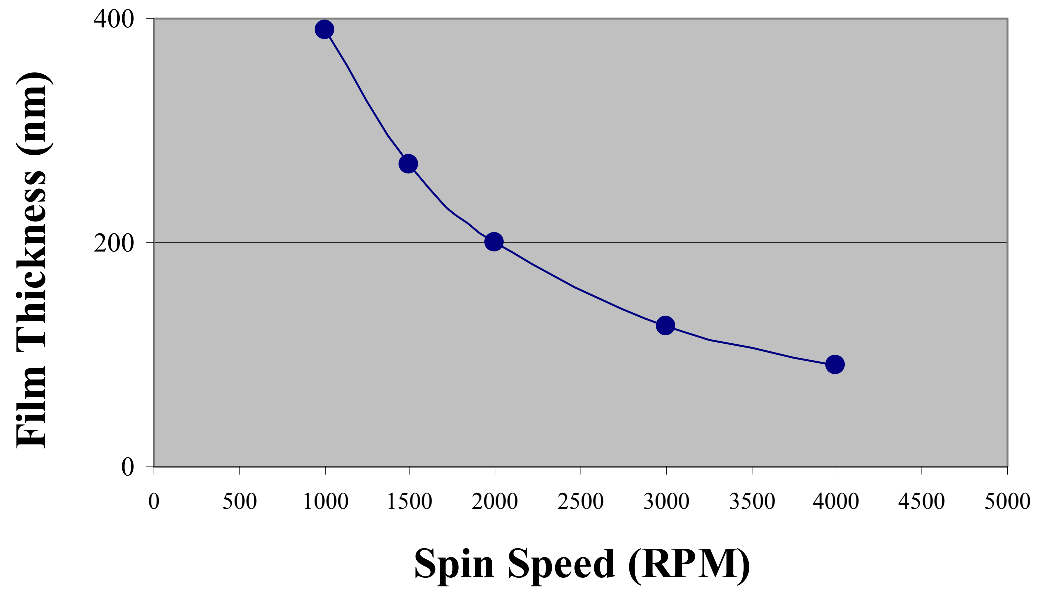
PMMA Developing Procedure

1. Prepare 20 ml of developer (3:1 IPA:MIBK) and IPA in labeled beakers.
2. Immerse the sample in developer for 70 seconds.
3. Rinse sample with IPA.
4. Dry sample with Nitrogen gun.
5. Postbake in 95 degree convection oven for 30 minutes.

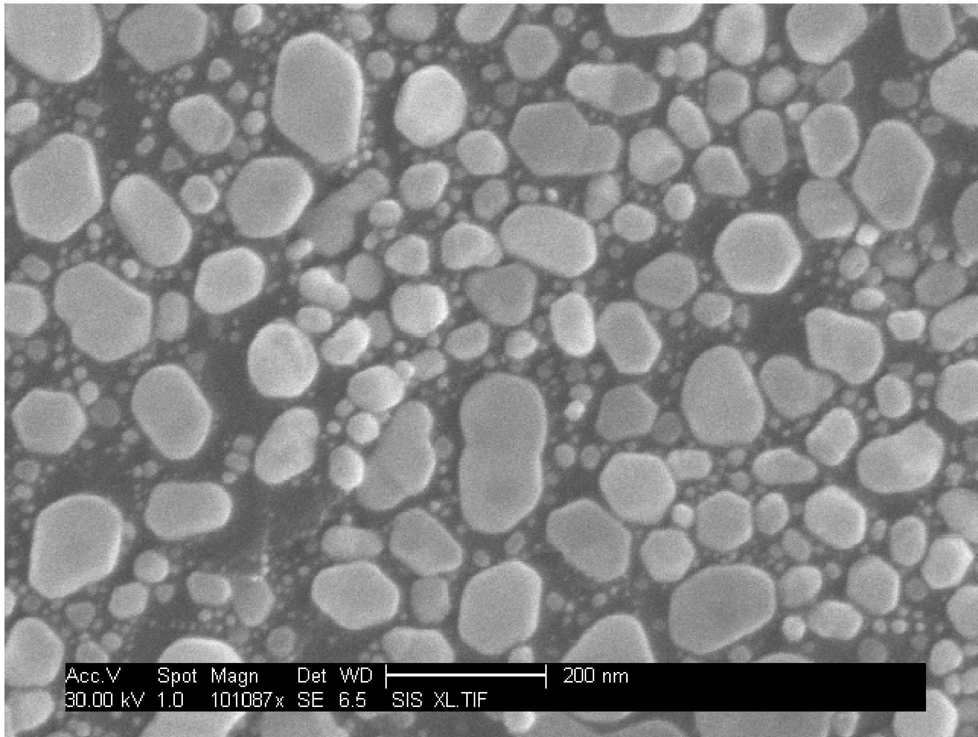
SEM Imaging on Written Patterns

1. Sputter ~ 50 Angstroms gold for SEM characterization (20-30 second).
2. Accelerating voltage: 7 kV/Spot Size 4.
3. Detector: TLD.

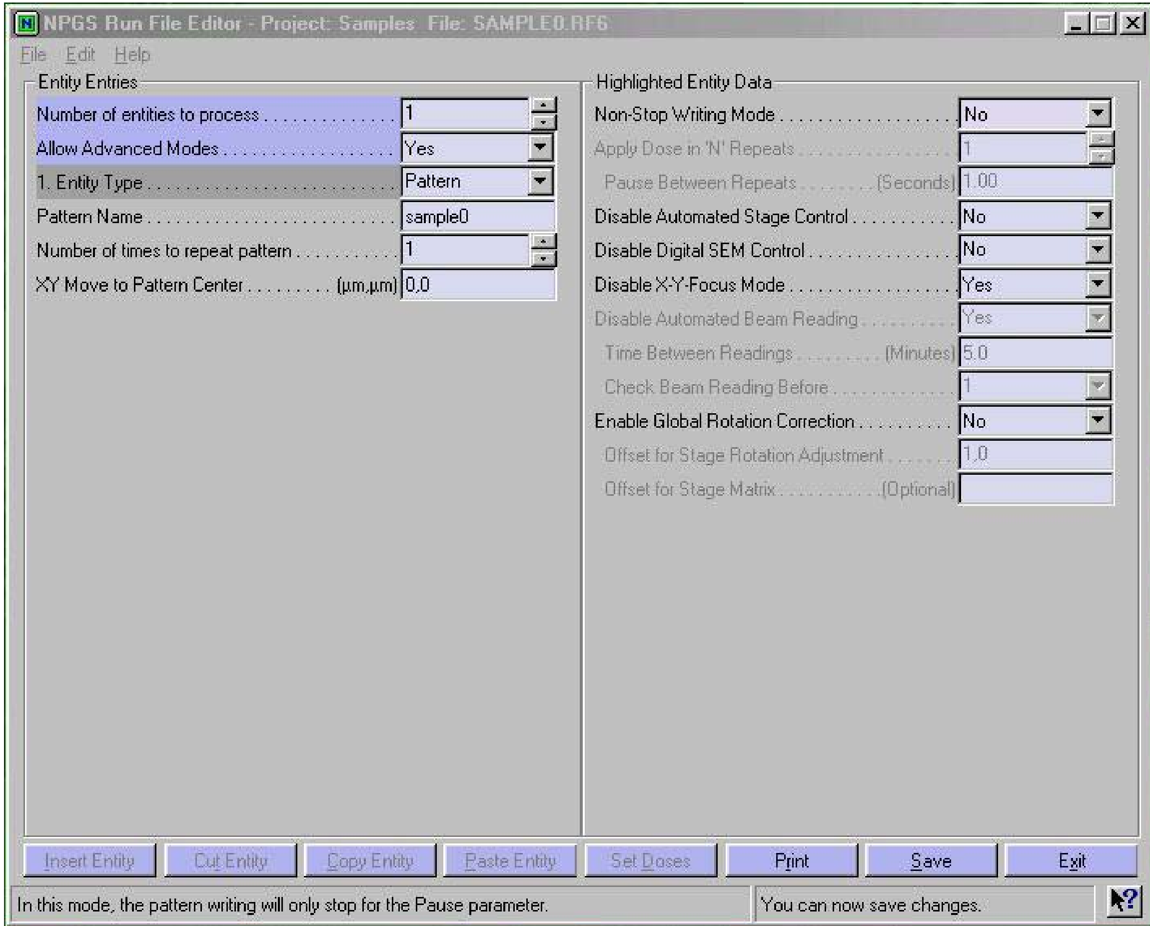
Appendix 1. Spin Curve for 950K PMMA 3% in Anisole



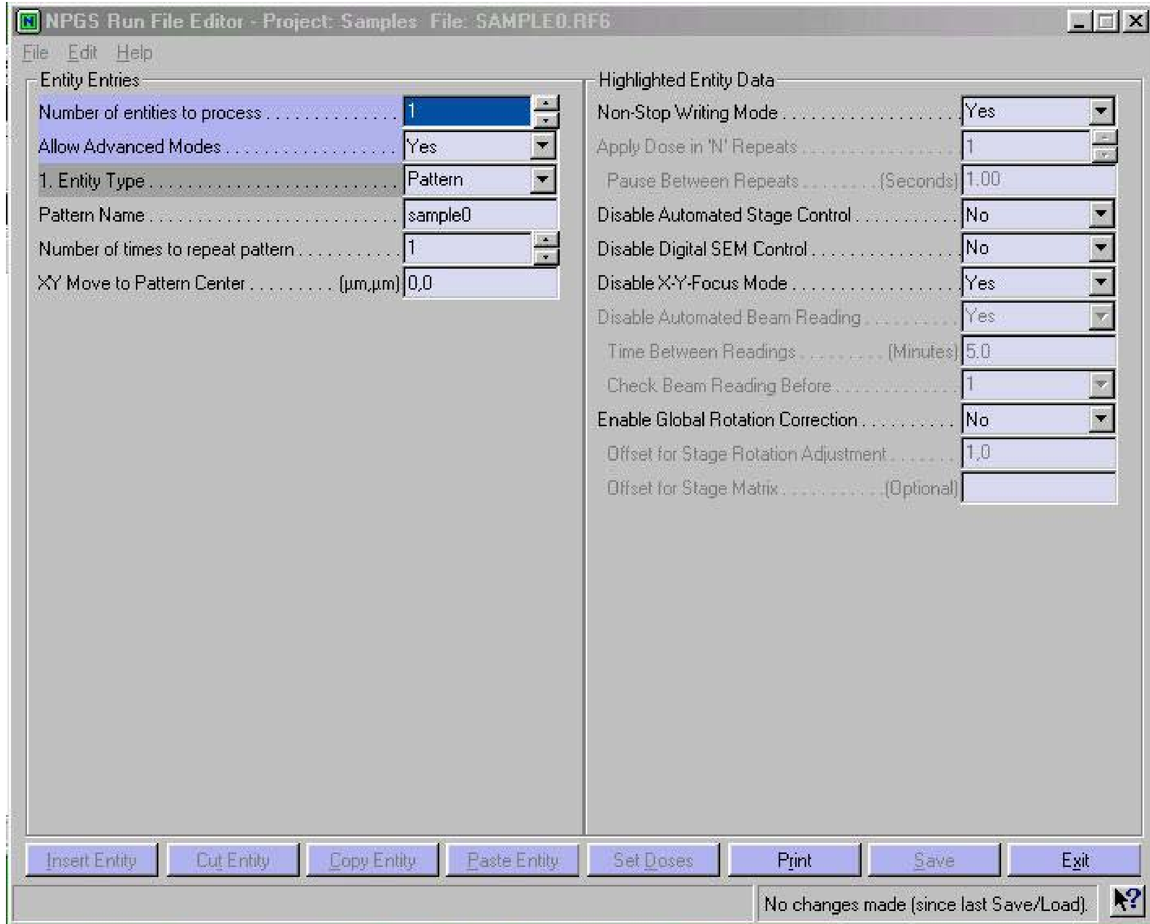
Appendix 2: An SEM Image of gold standard sample at working distance of 6.5 mm with optimized beam condition.



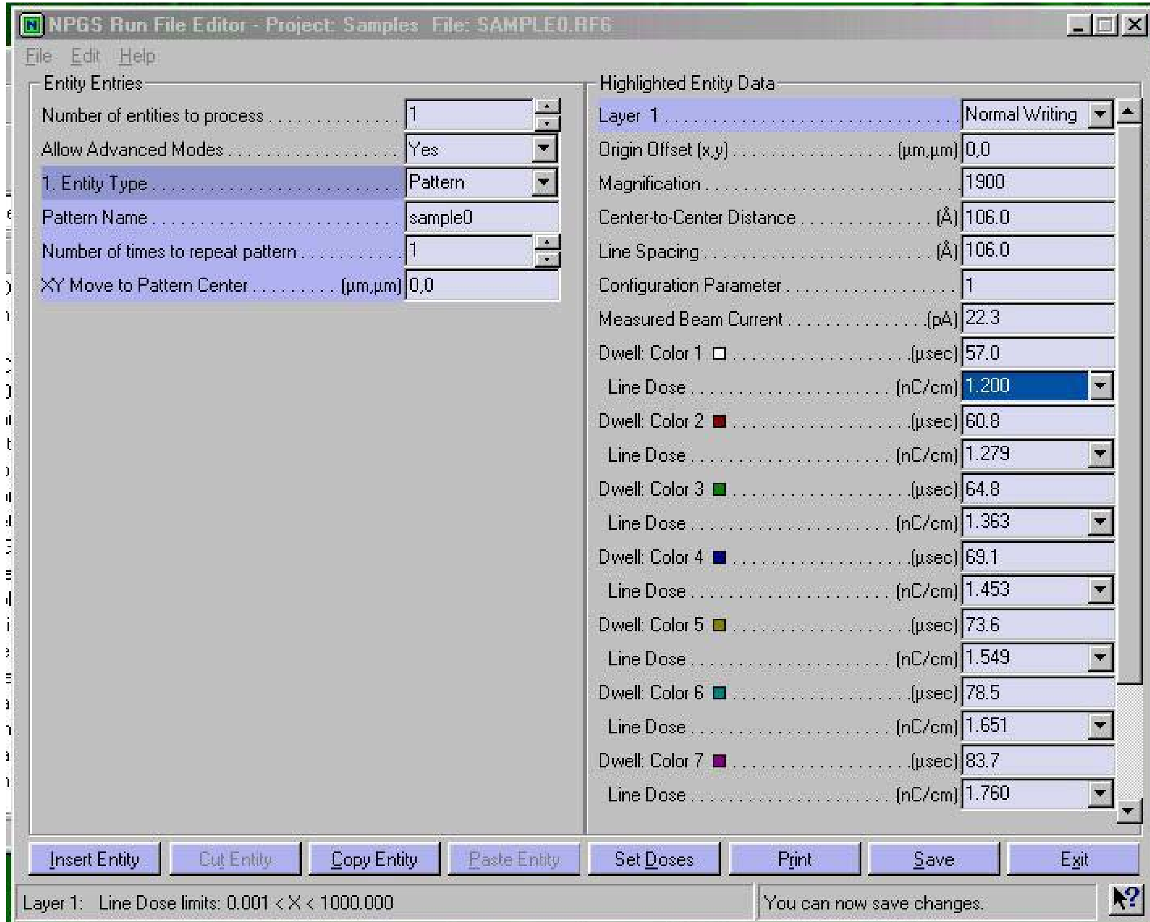
Appendix 3. An NPGS Run File Example - Time Test Advanced Settings.



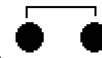
Appendix 4. An NPGS Run File Example - Process Run File Advances Modes



Appendix 5. An NPGS Run File Example - Sample0.rf6 using Line Dose



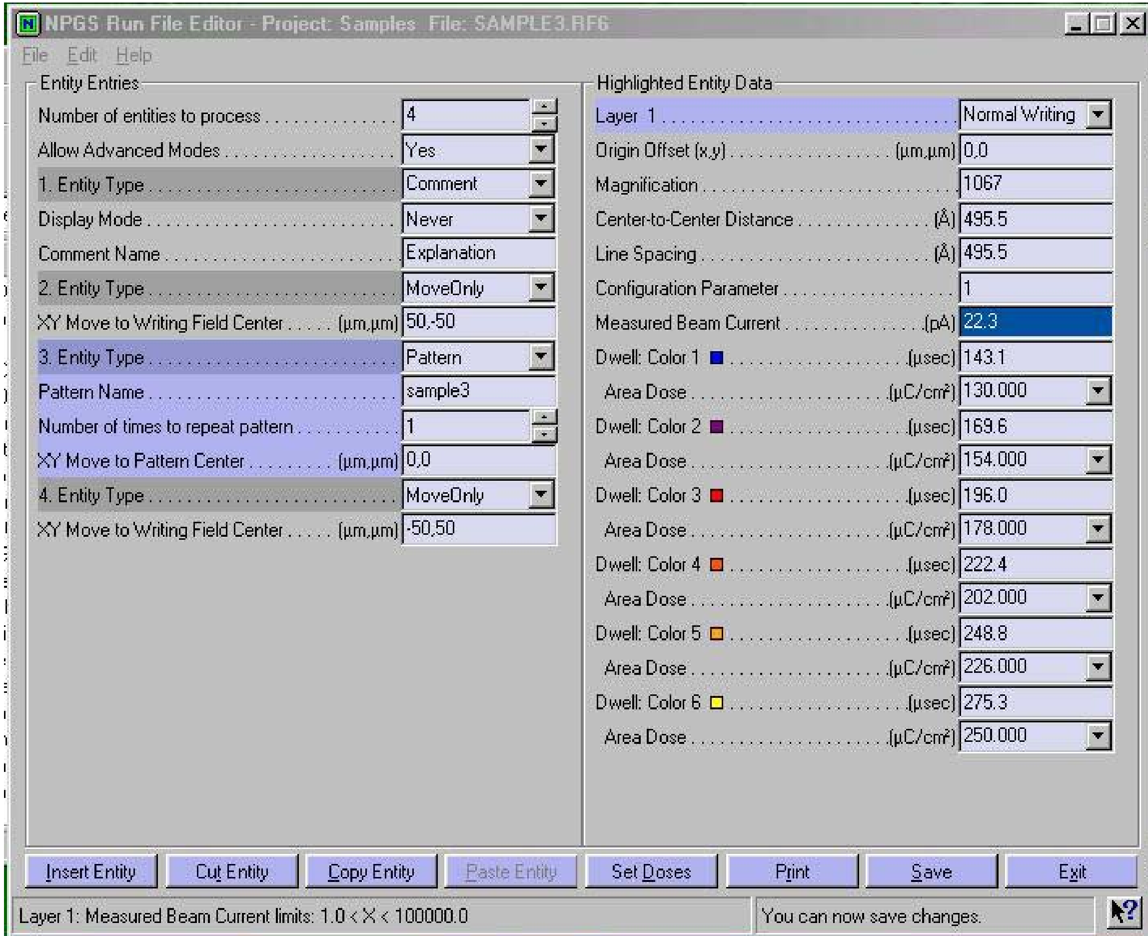
***Notes:**

Center-to-Center distance: Horizontal distance between exposure points. 

- For writing high resolution features, this value should be approximately ½ of final line width.
- To generate an array of dots, this distance should be set at a high value so as to space the individual exposure points far apart.

Line Spacing: Same as center-to-center but in the vertical dimension. Typical values are same as center-to-center.

Appendix 6. An NPGS Run File Example - Sample0.rf6 using Area Dose



***Notes:**

Center-to-Center for area doses should be set to a small enough value to ensure sharp corners and edges. However, do not under estimate this value. Doing so will add unnecessary exposure points and increase writing time.