EVO MA10 Scanning Electron Microscope

Sep 22, 2014

Location: W6-024
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OVERVIEW
The EVO MA10 SEM is available to users who require relatively high resolution imaging of various samples. The SEM is equipped with a secondary electron (SE) detector, and a backscattered electron detector (BSD). The maximum resolution of the MA10 is ~50nm, but is dependent on the sample, SEM condition, and the operators’ skill.

An environment designed for success.
SAFETY PRECAUTIONS

Normal laboratory practices apply. Gloves must be worn when handling anything entering the SEM chamber, including samples to reduce contamination of the sample and equipment. Failure to do so will result in poor imaging, higher base pressure, decreased filament life and increased down time.

Samples that are flammable (i.e. hydrocarbon-based), or exhibit high vapour pressures (i.e. due to evaporation or sublimation) are not allowed in the chamber.

Users must be careful when raising and tilting the stage; crashing the stage and/or samples into the lens and the sides of the chamber can cause damage to the equipment. Follow the outlined procedure when performing these actions.

*If you are bringing any new materials into the NanoFab for use in your process, it is necessary to fill out a chemical import form [available on our website, http://www.nanofab.ualberta.ca] and supply an MSDS data sheet to Stephanie Bozic.*

PROCESS COMPONENTS OR FEATURES

Samples should be clean, dry and mounted on an aluminum stub. Double sided carbon tape, aluminum stubs, and sample holders are available through the nanoFab, please contact Melissa Hawrelechko.

Non-conductive samples should be sputter coated with a conductor; a gold sputtering unit (Denton) is available at the nanoFab for this purpose. Contact Scott Munro for training.

OPERATING INSTRUCTIONS

1. The SmartSEM GUI program should be already running, but if not, double click the SmartSEM icon to startup the program. You will be prompted for a username and password. Use the default login:
   Username: ee457
   Password: micron

2. To simplify the startup procedure, ensure the stage and software settings are properly set at their home positions, as follows:
   Stage positions: X = 40mm, Y = 40mm, Z = 0mm, T = 0mm

3. Vent the chamber by selecting the Vacuum tab on the SEM Control window, and press Vent. It will take ~90s to fully vent; wait until the chamber door can be opened easily, do not attempt to force the door open.
4. The standard holder is a circular stub holder, designed to hold up to 9 sample stubs. Load your samples in the appropriate slots. If you are planning on imaging tilted samples, orient your samples so the features of interest are facing towards the outside edge.

Each slot is numbered for easy reference in the software. Gently tighten the set screw to fix the sample to the stage. Note that there are 100mm and 150mm wafer holders that can be swapped out in place of the 9 stub holder. Contact nanoFab staff if you require the use of either of these.

5. Close the chamber door until the door is in contact with the main chamber, and press the **Pump** button on the SEM Control window. It will take several minutes for the chamber to reach base pressure. The lower the pressure can reach, the greater the improvement in image quality. It is recommended to let the base pressure reach <2.0e-5 Torr before starting the beam.

6. During pumpdown, the stage may be moved and software settings adjusted as required. The stage home positions are as follows, indicated on the Stage Navigator window. If the navigator window is not displayed, it can be opened under the Stage menu, then Navigator. Stage positions: X = 40mm, Y = 40mm, Z = 0mm, T = 0mm

7. The stage may then be moved to the required imaging position, and beam settings adjusted as necessary. Ideally the sample should be raised closer to the pole piece in order to reduce the working distance (WD) and improve imaging. Higher magnifications and BSD usage will require a reduced WD, with an ideal range of 7-12mm. Tilting will have to be performed before raising the stage. As a general rule, always perform tilting with a Z height of 0mm.
Users are required to use the camera when raising or tilting the stage to avoid contact and potential damage to the system. Select the camera by pressing the Camera button on the keyboard. Adjust the Z height by moving the joystick in the Z+ direction until the sample is just below the pole piece and SE1 detector.

If tilting of the stage is required, first ensure the Z height = 0. Tilting with a high Z height may result in damage. First ensure the sample of interest is located at what will be the top of the tilted stage, around the 6:00 position, closest to the camera. Rotate into position as required. Begin tilting by adjusting the joystick in the T+ direction until the sample is at the desired angle. If raising the stage of a tilted sample is to be performed, use extreme caution as the WD is already reduced due to the tilt. Always lower the Z back to 0mm when tilting to lower or higher angles. Note the tilt will move the sample in the Y+ direction, track the sample by moving the stage in the Y- direction.

**Adjusting Beam Settings:**
Some Gun settings may be adjusted depending on sample requirements.

**Beam Current** – Default setting of 50uA.

**Iprobe** – Default setting of 5pA when using SE1 detector, ~5nA for CZ BDS usage. Lowering the Iprobe will decrease the spot size, but will increase noise.

**Fil I** – Filament current. Do not adjust this setting, only to be changed by nanoFab staff.

**EHT** – Extra High Tension (accelerating voltage), controls the energy of the beam. Available range is from 200V to 30kV. Higher voltages result in higher resolution, but increases penetration depth, making surface structures more difficult to image, as well as increasing potential charging and damage. Default voltage is 20kV.

![EHT Range 200V – 30kV](image)

![Do Not Adjust](image)

Gun Settings tab, double click desired cell to make changes.
8. To start a beam, select the **Gun** tab, click the Beam State drop box, and change the **Beam State to On**. It takes a few seconds to ramp up the current and EHT voltage to their respective set points; wait until the current is finished ramping before adjusting controls.

9. Once the current and EHT have reached their set points, an image should be displayed on the screen. If not, a number of things may be the cause. Ensure the scanning is not frozen (indicated by a red or blue dot on the bottom right hand side of the screen), or the brightness/contrast settings are not too low. Also ensure the magnification is at a reasonable starting point, ~50X is a good place to start. Verify the SE1 detector is selected under the Detectors tab, and that the Beam settings match the defaults in step 6.

10. To find the sample of interest, use the joystick and move the stage until the sample is in view, or use the Stage navigator and double click the slot number where the sample is loaded. The stage will automatically move to that position.

11. Once the sample and/or features of interest are in view, the magnification may be adjusted as required. Rotate the **Magnification** dial clockwise to zoom in, counterclockwise to zoom out. Samples with small or difficult to find features may require initial magnification and focusing to be performed on an edge before moving to the area of interest.

12. During adjustment of any setting using the keyboard, an updated setting is displayed in the upper right hand corner. Note that the sensitivity of any keyboard control can be set to Fine or Course by clicking the **Fine/Course** icon.

13. As the magnification is increased, the focus will inevitably become worse. Stop increasing the magnification and adjust the focus as required. To adjust the focus, rotate the **Focus** dial clockwise or counterclockwise until the image quality is improved. It may help to use the **Reduced** window feature with increased scan speeds to improve image quality. Alternate between the Magnification and Focus dials until the desired magnification level is reached.

14. **Reduced** window scanning is done by pressing the Reduced button on the keyboard. A smaller scanning window will appear, and the image will continue to scan within this window. Move the window by clicking and dragging anywhere on the border, and resize as required. Adjust any settings as required using the reduced window, and when done, press the Reduced button again to apply the changes to the full scanning window.

Note that the mouse may control some settings, typically the brightness, when clicked and dragged across the scanning window. Be aware when moving or adjusting the reduced window.
15. **Scan Speed and Noise Reduction** – To further improve the image quality, the Scan Speed and Noise Reduction values should be increased. Click on the **Scanning** tab to access the settings. The combination of the scan speed and N value will determine the cycle time. There are also various types of noise reduction settings available, with Line Avg being the default. Others may be selected as required.

   It is recommended that the speeds be kept low when moving the stage, and increased only when a higher resolution is required.

16. **Brightness and Contrast Control** – Improve the image by adjusting the brightness and contrast controls as required. There is no set value for these, and are determined by sample type, stage positions, scan speeds, and user preference.

17. **High magnification imaging** – If imaging at magnifications >5kX, additional adjustments may be required if necessary. There should be an area of interest already centred and focused.

   a. **Stigmation** – Corrects for any astigmatism of the beam. Begin by adjusting the Stigmator X dial and attempt to achieve the best image possible, and repeat with the Stigmator Y dial. Repeat until the best image is obtained.

   b. **Focus Wobble** (aperture alignment) – Press the **Wobble** button on the keyboard to open the reduced window and begin the scanning. The SEM will scan through a range of focal points, with the feature coming in and out of focus. If there is any lateral movement, the aperture requires alignment. The micrometers are located on the column of the SEM. Adjust one micrometer at a time to minimize the movement, again alternating until the movement is minimized.

18. **Image Capture and Annotations** – To capture an image, the image should be frozen to prevent drift and interference. Press the **Freeze** button (note the freeze setting should = End Frame on the Settings tab). The image will finish the scan and freeze once done. A yellow dot will appear indicating the scan is still scanning, and will change to red or blue once frozen.

19. Once a high quality image has been obtained and the image is frozen, measurements, annotations and image saving may be performed. Saving or performing measurements while the image is still scanning is not recommended as the image may drift over time.
20. Many annotations may be applied to the image as required. When performing any measurement, ensure the mouse is clicked and dragged to avoid freezing the software. Single clicking during annotation measurements may result in a frozen SmartSEM window, and requires a force shutdown to resume imaging.

21. When saving an image, ensure the correct directory is selected. Do not save to the desktop. Be sure to transfer your images in a timely manner to avoid losing them.

22. Press the Freeze button to unfreeze the scan and return to normal imaging. If adjusting the stage or other controls, it is recommended the scan speeds be reduced to reasonable values.

23. Shutdown Procedure – Once imaging is complete, users are required to reset the SEM software back to its original state before turning off the beam and venting.

   a. Remove all annotations from the image window.
   b. Reset the Scan Speed to 3 and the Noise Reduction N value to 2
   c. Lower the magnification to the lowest possible setting.
   d. Lower the Z height to 0.
   e. Lower the Tilt to 0.
   f. Click the centre of the stage on the navigator to centre the stage (X, Y should be close to 40mm)
   g. Return the brightness and contrast levels to a reasonable setpoint.
   h. Adjust the focus to a reasonable level. Users should be able to see a clear image of the stage.

24. Once the settings have been reset, turn off the Beam by changing the Beam State to Off in the Gun tab. Allow the filament to cool for several minutes before venting.

25. Vent the chamber and remove samples. Once removed, close the chamber and click Pump to keep the chamber under high vacuum. Leave the software program running.
TROUBLESHOOTING

The filament will inevitably be blown, and can happen at any time. If this occurs during your session, follow the shutdown procedure, and fill out the facility concern form found on the nanoFab website. The system will require cleaning and re-installation of the filament, and will be down for some time. The concern form can be found here:
https://admin.nanofab.ualberta.ca/report-concern.php

The software may freeze, and is somewhat common when performing annotation measurements. It can be avoided by dragging the mouse instead of single clicking when measuring between two points, but in the case of the SmartSEM freezing, a force shutdown is required. Ctrl-Alt-Del to bring up the task manager, then close the SmartSEM program. Restart SmartSEM; the settings and imaging should be where they were before it was frozen.

If you encounter an unexpected error or require assistance please contact the primary or secondary trainer listed above. Should they not be available, please contact any staff member for assistance.

APPROVAL

Qualified Trainer: Scott Munro
Training Coordinator: Stephanie Bozic
Appendix A – General Imaging Information
If the system is turned off or requires a full shutdown for whatever reason, certain settings will be reset. Users may also use this as a guide to ensure proper settings if imaging is difficult.

Secondary Electron Detector (SE1) Standard Settings:

**Scanning**
- Operating Mode = Normal
- Store Res = 1024 x 768
- Scan Speed = 3
- Freeze On = End Frame
- Noise Reduction = Line Avg
- N = 2

**Gun**
- Beam I = 50uA
- I Probe = 5pA (for CZ BSD = 5nA)
- Aperture Size = 30um
- Fil I = 2.3-2.7A (Do Not Adjust)
- OptiBeam = Resolution
- EHT = 20kV

**Detectors**
- Signal A = SE1
- Collector Bias = 400V
- Auto BC = Off
- Brightness = ~49%
- Contrast = ~35%

**Stage**
- X, Y = 40mm
- Z = 0mm
- T = 0mm
- Track Z button and Safe Navigation boxes checked
Focus Wobble – aperture alignment

Gun Tilt and Shift Controls – Do Not Adjust!!

IR Camera Mode

Stigmators

Reduced window scan mode

Scan Speed Controls

Keyboard + SEM Control Panel

An environment designed for success.