NCMN
Nebraska Center for Materials and Nanoscience
University of Nebraska

E-Beam Lithography Procedure

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1 Introduction

1.1 Key Words

E-beam lithography, Nanolithography, ZEISS Supra^{40} SEM, Raith Elphy Pattern Generator

1.2 Purpose

This document provides instructions for the E-beam lithography tool. Use of this tool requires the understanding of the fundamentals of lithography, SEM and the processing of resist.

1.3 Applicability

1.3.1 Locations

The E-beam lithography tool is located at **Clean room of nanoscience research center**.

1.3.2 Restrictions and Limitations

- Never put in "sticky" things. All samples should have been cleaned properly in appropriate solvents before being put into the sample holder.
- Never put anything that can evaporate contaminations inside the vacuum chamber. Vacuum is usually 1.0×10^{-6} mBar (1.0×10^{-4} Pa, 8.0×10^{-7} Torr).
- Never put in something with large height. Any samples over 2mm high must be approved by the specialist.
- All new resists or other materials that are planned to be used in the tool and are not covered by this procedure must be approved by the specialist.
- Good electrical contact is necessary to avoid charging of sample. Charge-up of electrons makes it impossible to get good images with the SEM.

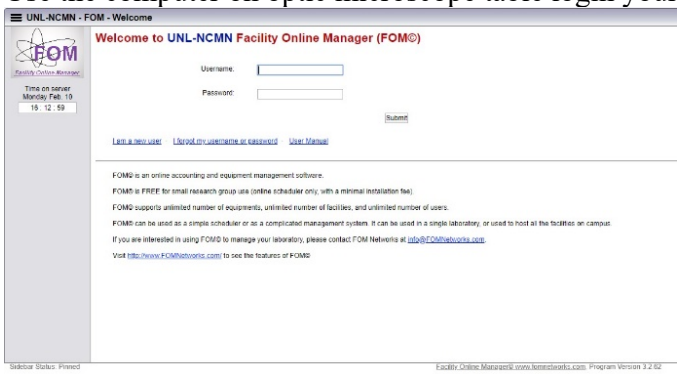
1.4 Restrictions on Working Alone

- Normal working hours are from 8am to 6pm M-F.
- Working alone is permitted with completion of an orientation to this written procedure and hands-on training from the specialist.
- The user must reserve the time through online calendar in advance. **Any samples left inside the chamber by the previous user will be taken out** without notification.
- Assistance from the specialist is available during working hours only. If an error occurs during off-hours, record the error in the Logfile and send an email to the specialist. **Do not try to fix or adjust anything by yourself.** Tool will be checked in the following work day. User will be notified when sample left in chamber is available for pickup.
- Problems with equipment malfunctions, breakage, etc. should be reported to the specialist and recorded in the tool Logfile. **Again do not try to fix or adjust anything by yourself.**
- For any emergency involving injuries, fire, chemical spills, etc., call **911.**

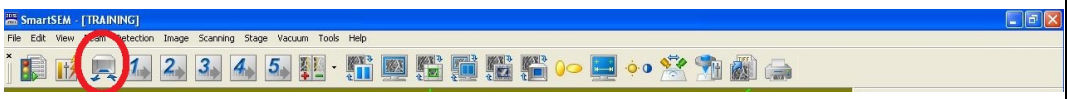
2 Preparations

- Complete *Training to the processing of the resist*.
- Receive this procedure from the specialist.

3 Execution (Step-by-step work breakdown)

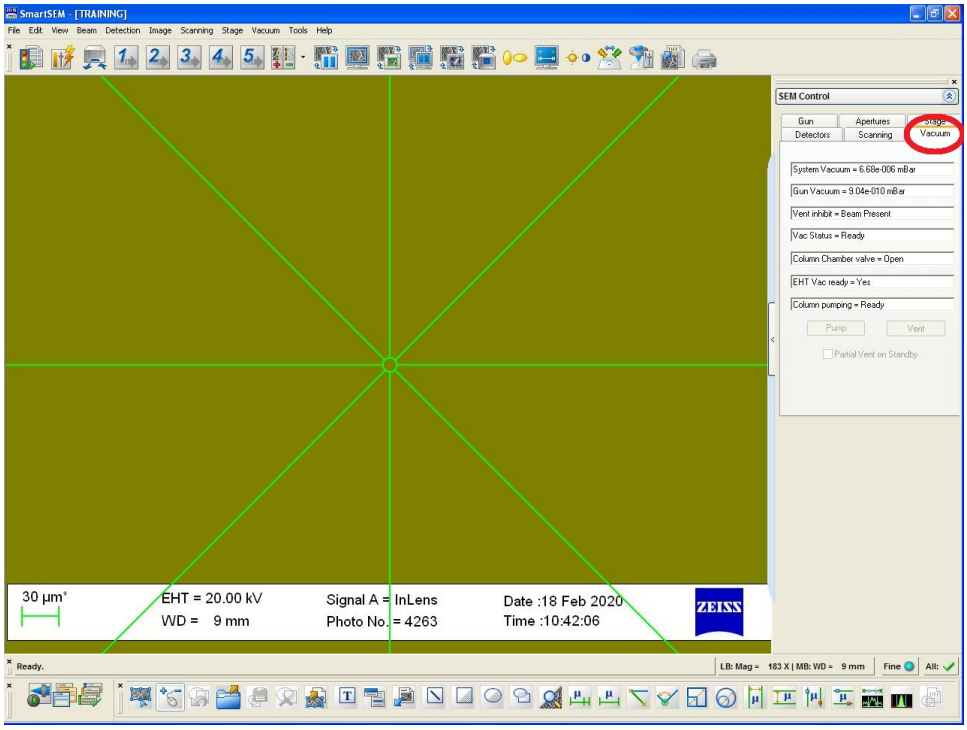
Step #	Action
1.	**Logon equipment through NCMN FOM**: • Use the computer on optic microscope table login your NCMN FOM account.  • Locate equipment "NANOFAB - EBL" and follow the screen to logon the equipment • Once the equipment is logon, the screen of RAITH (left) will turn on automatically. **Opening Software: (**The system consists of a Scanning Electron Microscope (SEM) from ZEISS integrated with electron beam lithographic pattern generator from Raith.**)** • Double click the "SmartSEM User Interface" on the desktop (**right computer, it is called "ZEISS" below for convenience**) and login the ZEISS SEM software. • Log into the Windows account in the Raith Litho PC, then open the "ELPHY Quantum" software on the desktop and log in. (**left computer, it is called "Raith" below for convenience**). • The ZEISS SEM software MUST be running before starting the "ELPHY Quantum" software.

2. Loading Sample:



- In **ZEISS,** click button  ("Specimen Change/Vacuum Control"). A warning window ("the stage is not initialized…") will pop-out. Click on "ok" in this window. The system will start venting and a micro message window ("click ok to pump") will pop-out. ***Do not click on "ok" in this window now*** and wait 3- 5 minutes until the chamber is vented.

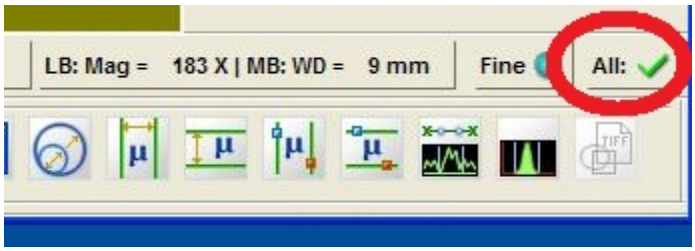
- Open the chamber gently and load wafer/sample. Use clips to hold wafer in place. There are three positions ("top right", "top left" and "bottom left") that can be used. ***(If samples are over 2mm high, they must be approved by the specialist.) Do not use metal tweezers***. They will scratch the stage chuck.
- Close the chamber gently. Click on "ok" in the micro message window. Gently hold the door of the chamber until the pump works smoothly. It will take about 10 minutes to pump the chamber down to good vacuum (~1×10^{-5} mBar). It is shown in the "SEM Control" window in **ZEISS** by clicking on the tab "Vacuum".



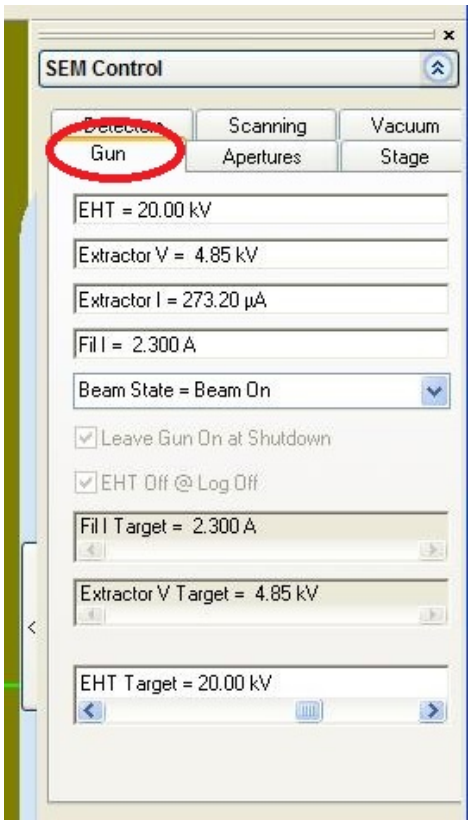
3. Turn on high voltage, aperture selection:

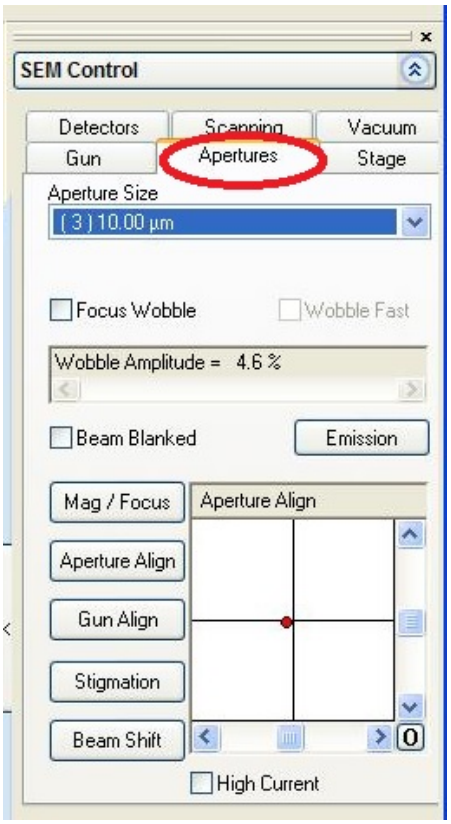
- Apply the value of High Voltage by clicking on the tab "Gun" in the "SEM control" in **ZEISS** and then clicking "EHT=" item to **check/enter** the suitable value. (A value of 30KV is good if the sample has a resist thicker than 500 nm. For samples with resist thinner than 200 nm, 10 KV is OK. In between, 20KV can be used). At the right bottom corner of the SEM window in **ZEISS**, right click the Red Cross behind "EHT" and then click on "EHT ON" in the shortcut menu.
- Check the status of the system. If the system is ready, a green tick 

will show up at the right bottom corner of the SEM window in **ZEISS**. Next to it is the control status switch. Click to change the system to "fine" control status if "coarse" status is shown.



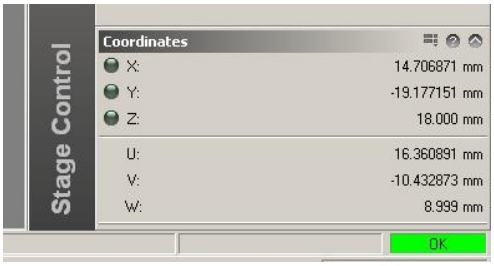
- Click on the tab "Apertures" and **check/choose** a suitable value for Aperture size in the pull-down menu under "Aperture size". This mainly decides the beam current. If higher currents are needed, use a larger aperture. **10µm** is recommended for most samples.

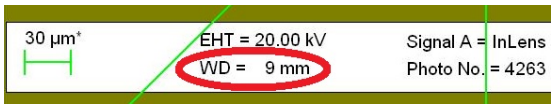




4. **Check WD (Working Distance):**

- In **Raith,** find the current values for Z and W in "coordinates" window located at the right hand side lower corner. W is the WD value. For most applications, the WD should be **9 mm**. ***If not contact the specialist to reset the stage.***
- In **ZEISS,** set WD on SEM main display by double-clicking "WD=..." in the Data zone at the bottom of the image window and put the same value used in **Raith**. (Generally the working distance is **9 mm**.) Working distances below 7.2 mm are not allowed (software limit).





5. **Log file entries:**

- The log file ("Logfile") is on the Desktop of **ZEISS** computer.
- Use the settings entered previously for acceleration voltage (EHT) and aperture (i.e. 20 KV, 30 µm aperture). Use the "SEM Control" window in **ZEISS** to obtain the information of vacuum levels and gun parameters for entries in log file.

6. **Finding Faraday Cup:**

- The stage should sit at the position of the Faraday Cup when loading/unloading the samples. The Faraday Cup is also used as the object for initial imaging as the following steps.
- In **Raith,** turn on the beam by clicking once on the button  ("Beam on/off"). This is an on/off button. Beam on/off status is displayed without or with the red-cross.

- In **ZEISS** turn on SEM scanning by clicking on the button  ("Normal/Scanning"). The scanning speed can be changed by clicking on the buttons  or "Scan speed"  . "2" or "3" are recommended.
- Check the suitable detector is used in the data zone at the bottom of the SEM image window in **ZEISS**. Normally "**INLens**" should be used for the applications with

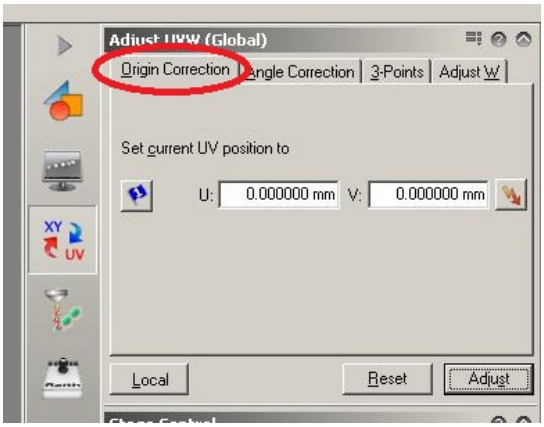
	EHT less than or equal to 20KV. If EHT is higher than 20KV, "**SE2**" detector should be used. Click button  ("Toggle InLens:SE2/Detector control") to switch.  • Adjust the contrast and brightness to the suitable values, reduce the magnification to the lowest and focus to obtain a clear SEM image of Faraday cup hole with the "Brightness", "Contrast", "Magnification" and "focus" knobs on the keyboard of **ZEISS** computer. ***If you cannot get image at this point, contact specialist for help.***  • Turn off the beam by clicking once on the button  in **Raith** and Switch SEM scanning to camera by clicking "Chamber scope" button  in **ZEISS** for the next section.
7.	**Finding sample corner:** • Move the stage to the position where the sample locates by choosing the tab of "Positions" in the window "Stage control" and selecting the corresponding position ("top right", "top left" or "bottom left") in **Raith,** then clicking on the "Go" button. *(Note: The beam blank will close automatically when the stage makes a quick move.)* Wait until the stage finishes moving before continuing. • Turn on the beam by clicking once on the button "Beam on/off"  in **Raith** and start the SEM scanning by clicking on the button  ("Normal/Scanning") in **ZEISS**. Now the SEM image should show up in the **ZEISS** again. Use joystick to locate the lower left corner of the sample and move it to the center of the image. • Look for a small particle (less than 10μm) to focus on it under suitable magnification. It is strongly suggested to put a small scratch on the corner of your sample before loading your wafer. The scratch will provide many particles which can be used for focusing. ***Focus on a particle on the surface of the wafer not on the scratch itself.***

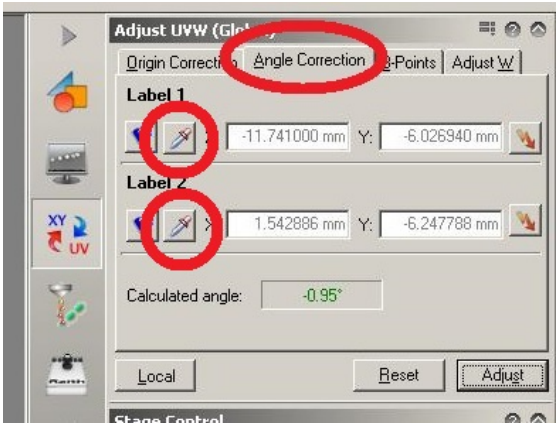
8. **Preparing coordinate system**

Coordinate systems:

Stage: **X, Y**: these are the stage coordinates.
Wafer: **U, V**: these are the wafer coordinates. They refer to the location on the wafer.
Design: **u, v**: these are the design coordinates. They refer to where features are located in each designed pattern.

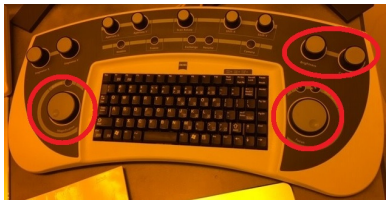
- Origin Correction:
  In **Raith**, Click on "Origin correction" tab in window "Adjust UVW". Find the position on the sample used for UV origin with crosshair, then click "Adjust". (If sample does have alignment marks use one as found in the pattern/chip design. If the sample is a bare substrate use the lower left corner for the origin.)
- Angle Correction
  - ***Do not move the stage.*** Click on "Angle Correction" tab in window "Adjust UVW", then click "read" in the coordinate #1
  - Find lower right corner of the sample (or the other alignment mark) with crosshair, click "read" in the coordinate #2 and then click "Adjust". The calculated angle should be close to zero and change to the green color.
  - Turn off beam and go back to coordinate #1 by clicking the "lightning bolt" button. Turn on beam and verify sample has not shifted.



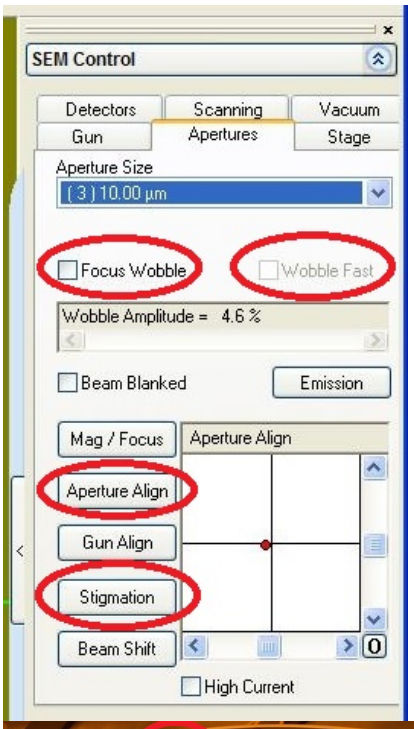


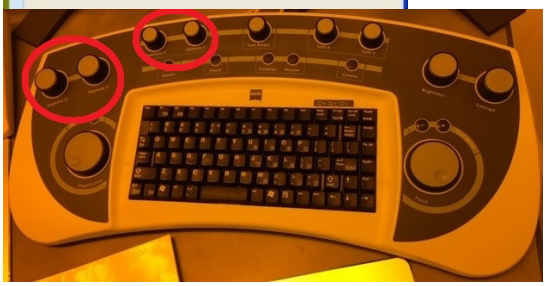
10. **Calibrating SEM column:**

- Find a small particle (1-2 µm in size) on the corner of the wafer; adjust to suitable magnification, brightness and contrast using "Magnification", "Brightness" and "Contrast" knobs on the keyboard of the ZIESS computer.
- Focus to get the clearest image of this small feature using big "Focus" knob on the keyboard of the ZIESS computer.

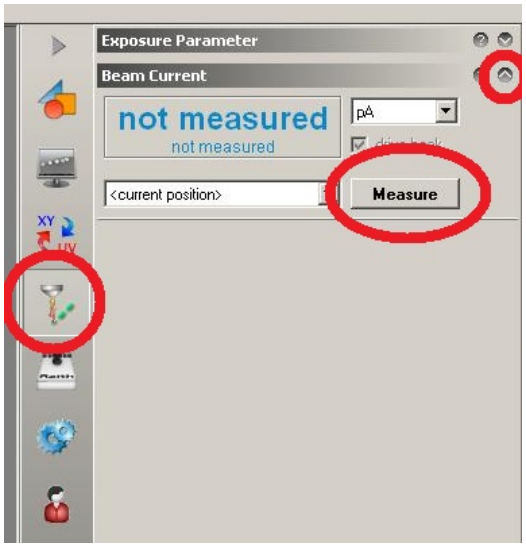


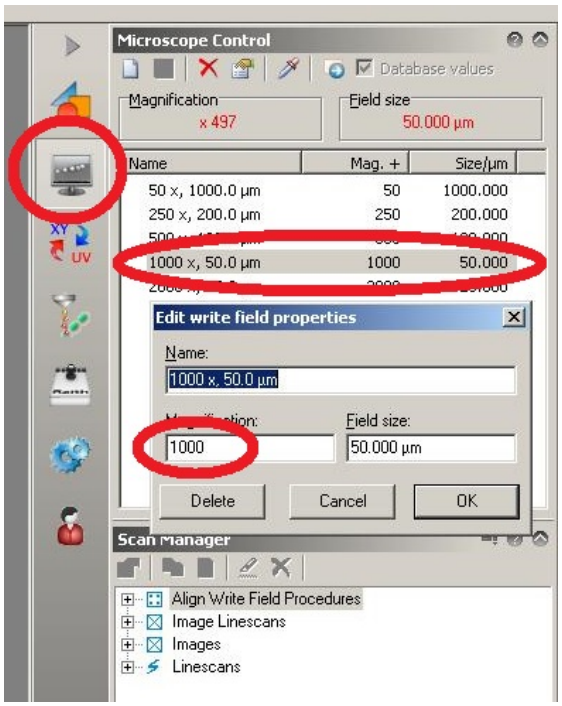
- Fine column alignment
  - Move the stage to some inner part of the sample (~1mm in both U and V). Burn a contamination spot by clicking the "Scan" tab in the "SEM control" in **ZEISS** and check the small box of "Spot". Wait for 30~60 seconds and then uncheck the box. A white spot should appear. If not, repeat coarse column alignment procedure to get a better image and then burn another contamination spot at different positions. **Re-focus at a suitable magnification.**
  - Calibrate stigmata by using "Stigmate X / Stigmate Y" knobs on the keyboard of the ZIESS computer to get the clearest image of the contamination spot. The feature should show equivalent sharp in up/down and left/right directions.
  - Click the "Aperture" tab in the "SEM control" in **ZEISS**. Check "Wobble" to find if feature is moving up/down or left/right. Use "Aperture X / Aperture Y" knobs to decrease the moving magnitude to the least. **Uncheck "Wobble" to stop wobbing.**



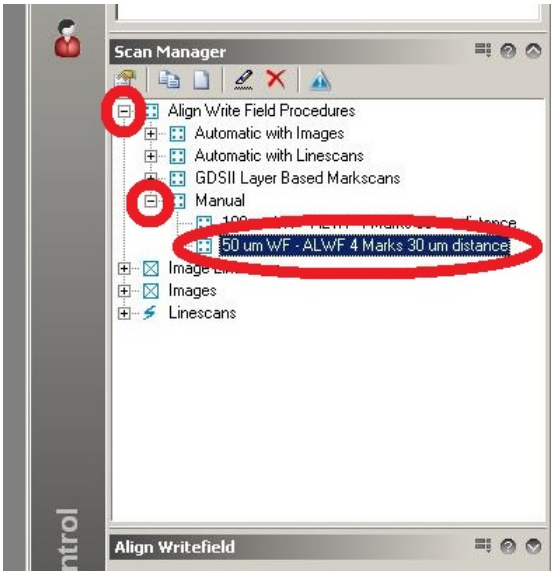


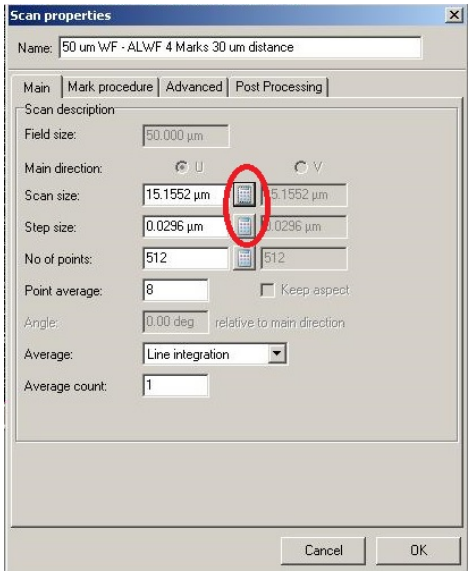
  - Repeat burn -focus- stigmate-apture steps at different location until a small (~ 20 nm) *round* spot is seen on screen. The stigmate-focus steps should be done with a magnification around 200KX at least. ***Make sure scanning is***

	not rotated in SEM software. Do not change any setting of the beam including focus, stigmate, and aperture from now on. Otherwise, the fine column alignment has to be redone. But magnification, Brightness and Contrast can be changed without readjustment. ○ To remember this location for future use (such as align write field) go to "Stage Control" window and "Destination" tab in **Raith**. Click on "dot" location and then click "Edit". Go to the new pop-out window, click "Read", and then click "OK".
11.	**Measure Current:** • Measuring current can be done at any time once the aperture has been set. It is preferable that it is done right before writing field alignment, 3-point adjustment and exposure so that the tool has had the time to settle. • Turn off beam by turning on the beam blanker in **Raith** (refer to step 7)**.** Switch SEM scanning to camera by clicking "Chamber scope" button  in **ZEISS**. Use "Stage Control" window and "positions" tab in **Raith** to choose "Faraday cup" and click "Go" to move the stage to Faraday cup. • Turn on beam by turning off the beam blanker in **Raith** (refer to step 7)**.** Switch to SEM scanning by clicking "Normal/Scanning" button  in **ZEISS**. Reduce to suitable magnification so that the whole Faraday cup hole fits into the SEM image and use joystick to move the crosshair to the center of the hole. • ***Increase the magnification to at least 50KX.*** In **Raith,** clicking on "Exposure" button  **,** then click "measure" in beam current window to measure the current. Record it in the Logfile in **ZEISS** computer.  • Turn off beam by turning on the beam blanker in **Raith.** Click on "Origin correction" tab in window "Adjust UVW" and click on the "lightning bolt" button to move the stage back to the defined UV origin.

	• Turn on beam and switch to SEM scanning to verify the origin has not shifted.
12.	**Align Write Field:** • In **Raith**, click on "Microscope Control" button . At the top part, the appropriate Write Field can be selected. If 50 µm write field is used, double click on item "1000x, 50 µm" and change "1000" to "990" in the pop out dialog box. Click the button at the top to activate the setting.  • Locate a particle, mark or contamination spot that has good contrast with background of SEM. For example, go back to find the contamination spot or particle used to focus and stigmate. (Go to "Stage Control" window and "Positions" tab. Click on "dot1" location and then click "Go".) • All WF-alignment procedures are available in the "Scan Manager" window which can be found by clicking "Microscope Control" button in **Raith**. They are grouped into different parts, such as Automatic with images, Automatic with Linescans, Manual, etc. The usual way is to do a Manual WF align for the appropriate (selected) WF-size. • Scan an image in **Raith** using button at the top left of the main window. A new window will pop-out. Click on "continuous scan" button on top of the window and adjust contrast and brightness to get a clear image. The reference particle should sit roughly in the middle of the image. Then click "single scan" button to freeze the scan. • Choose the WF-align procedures with the corresponding writing field under "Manual" in the "Scan Manager" window and set suitable parameters by ***right clicking*** on it and select "properties" in the shortcut menu. It is necessary to start

with quite big scan size about a quarter of the WF-size (i.e. 15 µm for a 50 µm WF). Click on the calculator symbol  next to the value for "step size" to get the right step size value and then click the one next to the value for "scan size". Click "ok" to confirm the change. ***Do not change the values of "No. of Points" and "Point average", which should always be set to 512 and 8 respectively. Contact the specialist if you want to set a new WF-align procedure.***

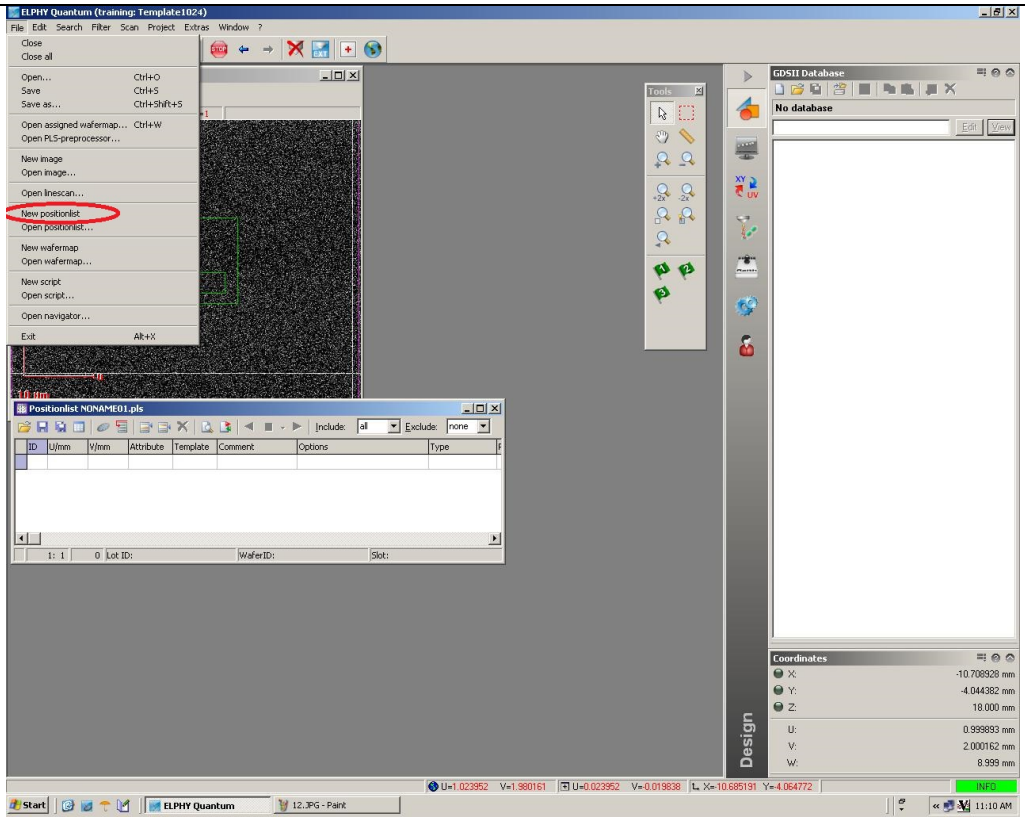




- Drag and drop the above WF-align procedure to the image in **Raith** so that the center of the scan area (the red square frame) is coincident with particle/contamination spot or alignment mark. A new position list window will pop-out automatically. Click on the "scan selected" button  to start scanning.
- Wait until the scan finishes. On the new image press "Ctrl" + left mouse button simultaneously, drag vector to particle/contamination spot or alignment mark. Click "Continue" to continue the next scan. There should be three image scans in total. ***Pick the same location for each scan.*** After all three image scans finish, click "Yes" in the "Accept" window to confirm the change.
- Right click on the WF-align procedure that is using in scan manager window and select "properties" in the shortcut menu. Change the WF-size to 5 µm and repeat the above procedure.
- Repeat with the 1 µ scans.

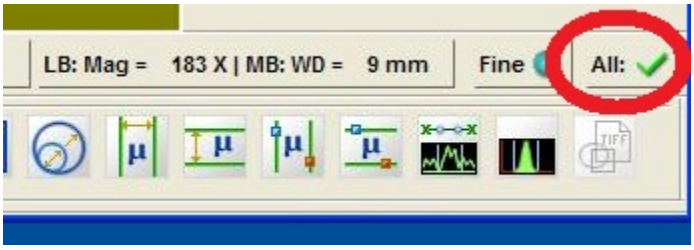
13. **Preparing PositionList:**

- Click on File in the main window of **Raith** and then click on New Position List.
- Click on "GDS II Database" button  in **Raith**. Click on File – Open and load a GDS file. A structure in an opened GDSII database can be selected and dragged into the position list.



14. **Setting exposure parameters:**

- Click on a structure in the Position List with right mouse button and click on "Properties" with left mouse button.
- First entry is for layers of structure that will be exposed; Second entry is for extents of structure; Third entry is for initial position in UV local coordinates of structure. ***Talk to the specialist if you have any questions about these parameters.***
- Click on "Exposure Parameter"
  - For area exposures uncheck boxes for Area Enable, area Step Size, and Dwell Time.
  - For line exposures uncheck boxes for Line Enable, Line Step Size, and Dwell Time. Line exposures also require unchecked boxes for area dose exposures.
  - For dot exposures uncheck boxes for Dot Enable, and Dwell Time.
  - If any one of area, line or dot exposure are not used in the structures, change the "Enable" to "Disable" in the pull-down check boxes.
- Click on "Calculator"
  - In calculator setup step sizes, and dose. Calculate dwell time.
  - Step sizes are determined by the size of the smallest feature in the design pattern. Normally it should be less than 1/10 of the size of the smallest feature.
  - Area Dose is always fix at 100. Change the dose in the designed pattern by

	changing the dose factor for different structures. ○ This leaves dwell time as the variable. Click on the calculator symbol  next to the value for "Dwell time" to get the right dwell time value. • Verify that beam speed is less than 10 mm/s. (Normally it should be ~5 mm/s). If beam speed is too high, the deflectors will lag the data creating exposure errors. Beam speed can be decreased with less current (smaller aperture size), or larger exposure step.
15.	**Run exposure:** • Click on "Scan" – All, or Actual in **Raith**. • A window with the particular structure to be exposed will show up. Wait until the exposure finishes.
16.	**Turn off high voltage:** On **ZEISS** click on button  at lower right corner of SEM window and then click on EHT OFF (***For expert users: Do NOT click on "Gun off"!***). Wait until the EHT is disabled. 
17.	**Unloading sample:** • Click on "Chamber Scope" button  in **ZEISS** to switch to the camera. • Use "Stage Control" window and "positions" tab in **Raith** to choose "Faraday cup" and click "Go" to move the stage to Faraday cup. • Click on button  ("Specimen Change/Vacuum Control") in **ZEISS**. A warning window (saying the stage is not initialized) will pop-out. Click "ok" in this window. The system will start venting and a micro message window will pop-out (saying click ok to pump). ***Do not click "ok" in this window now*** and wait about 3 minutes until the chamber is vented. • Open chamber gently and remove sample. (***Do not leave the chamber open for long time. It consumes large amount of venting N_2 gas and contaminates the laser interferometer fiber.***) • Close the chamber. Click on "ok" in the micro message window. Gently hold the door of the chamber until the pump works smoothly. Wait about 10 minutes to pump the chamber down to good vacuum (~1x10^{-5} mBar).

18.	**Closing software:** • Close the "ELPHY Quantum" software in **Raith** first. • Log out of Windows on **Raith** computer. • Log out of **ZEISS** SmartSEM software through the pull down menu "File"→"Log off" and then click "OK" to confirm in the pop-out window. ***Do not close it or use "exit".*** • ***Do not*** log out of Windows on **ZEISS** computer. • Exposure time and time Out entry in Logfile filled • Log off the equipment through NCMN FOM; Raith Screen will automatically turn off.
19.	**Tool conditions when finished** • Empty sample chuck in chamber. • **Raith** "ELPHY Quantum" software closed. • **Raith** PC Windows session logged out and the Screen is off. • **ZEISS** SmartSEM software user logged out • **ZEISS** PC Windows is running and NOT logged out
20.	**Clean up all samples, pens, and notebooks from the area.**
End	**End of Procedure**

4 Post-Performance

4.1 Recordkeeping

Completely fill out the electronic logfile on the ZEISS Computer.

4.2 Feedback

Report any unusual or problematic behavior of the setup by contacting the specialist.

5 References

5.1 Technical References

• **Raith** and **ZEISS** SEM Manual

6 User Access Level

Normal User – Requires specialist to be present

Expert User – Does not require specialist to be present