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RAITH 150^{TWO} SOP



Figure 1 The Raith 150^{TWO}

1. OVERVIEW

The Raith 150^{TWO} is an ultra-high resolution, low voltage (0.1 – 30 keV), electron beam lithography (EBL) tool. The tool is capable of writing sub-10 nm features, field stitching of ~ 25 nm, overlay alignment better than 40 nm, and can pattern structures over a 150 mm diameter wafer. Additionally, the system is also capable of fixed beam moving stage (FBMS) exposures, handling 7 inch masks, and automatic focus correction.

2. PROCESS COMPONENTS OR FEATURES

The Raith 150^{TWO} EBL tool has a number of associated components and features that its users must be aware of such as (i) universal sample holder, (ii) front panel controls, and (iii) joystick.

- (i) The **universal sample holder (USH)** contains numerous clips to hold chips in a certain orientation as shown in fig. 2 (below). This is in order to facilitate exposure and inspection. The bottom of the **USH** contains three locations for the piezo-levelers (visible in fig. 2; shown during training) which connect to the stage. The **USH** must be handled with great care.

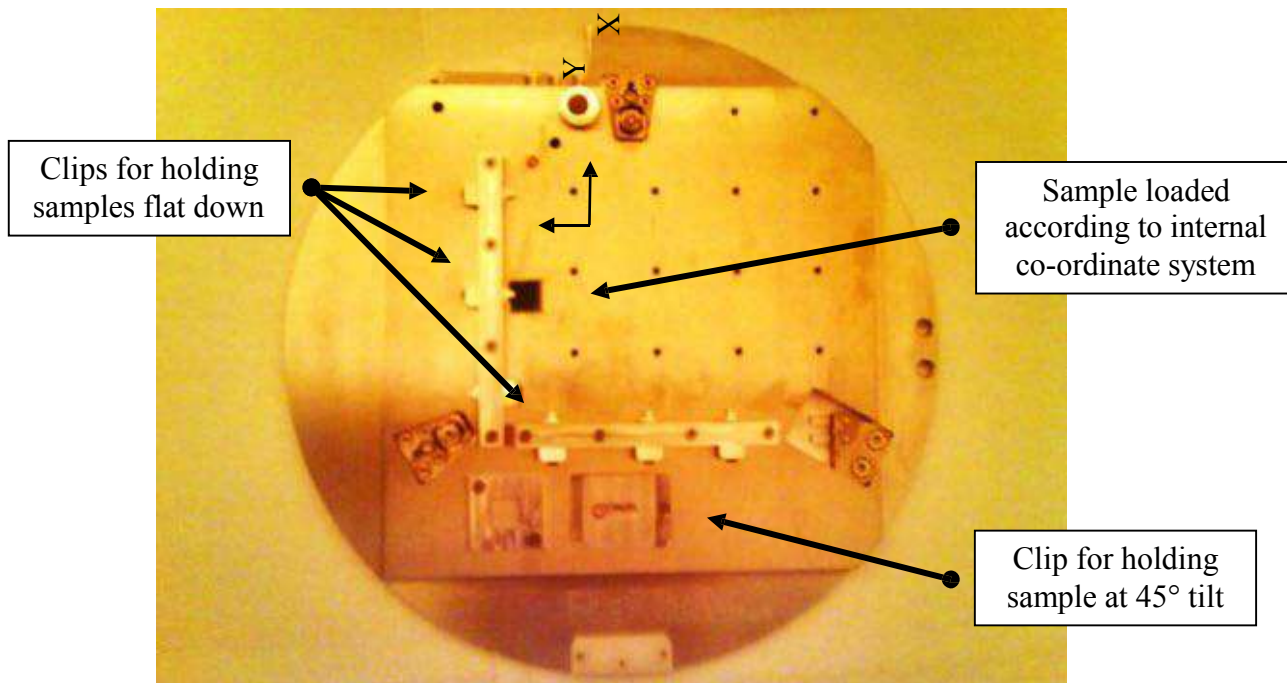


Figure 2 Universal Sample Holder (USH)

- (ii) The Raith 150^{TWO} EBL tool is enclosed in an environmentally controlled enclosure. This enclosure contains panels related to sample loading/unloading, wafer holders, and emergency controls etc., as shown in fig. 3.

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Figure 3 Panels of interest on Raith 150^{two} enclosure

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- (iii) The Raith 150^{TWO} EBL system includes a **joystick** which controls the motion of the stage / sample holder for easy and efficient navigation as shown in fig. 4.

For your convenience, you may turn on the X, Y, and 'Speed High' buttons as shown.

Fine movements will require the 'Speed High' button to be off.



Figure 4 Raith 150^{TWO} joystick

4. OPERATING INSTRUCTIONS

Once the sample holder is properly placed in the load lock, the sample can be loaded. Ensure that the load lock lid is closed.



1. Click on the Raith 150^{TWO} icon
2. A pop-up window will prompt the user to login as shown in Fig. 5. The **Login** button will remain disabled until the correct password is input. The project drop-down loads custom (saved) settings. By default, the program will use the settings from *your* previous session.

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RAITH150-TWO
Ultra-High Resolution E-Beam Lithography and Metrology Tool

Licensed to: NanoFab - NYU Tandon School of Engineering

User: Password:

Project:

Raith GmbH, Hayerl 18, 44227 Dortmund, Germany
Phone: +49 (0)231 975 000 - 99
Email: support@raith.de <http://www.raith.de>

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Figure 5 Raith 150^{TWO} login window

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- Another pop-up window will prompt the user to login to the electron microscope (EM) server as shown in Fig. 6. The username and password for the EM server is 'training'.



Figure 6 Electron microscope (EM) server login window

- The EM server window will pop-up as shown in Fig. 7 and initialization will complete in under a minute. Do not be alarmed in case you encounter a **5V supply failure** message. This usually disappears in a few seconds. Minimize the EM server window when initialization is complete.

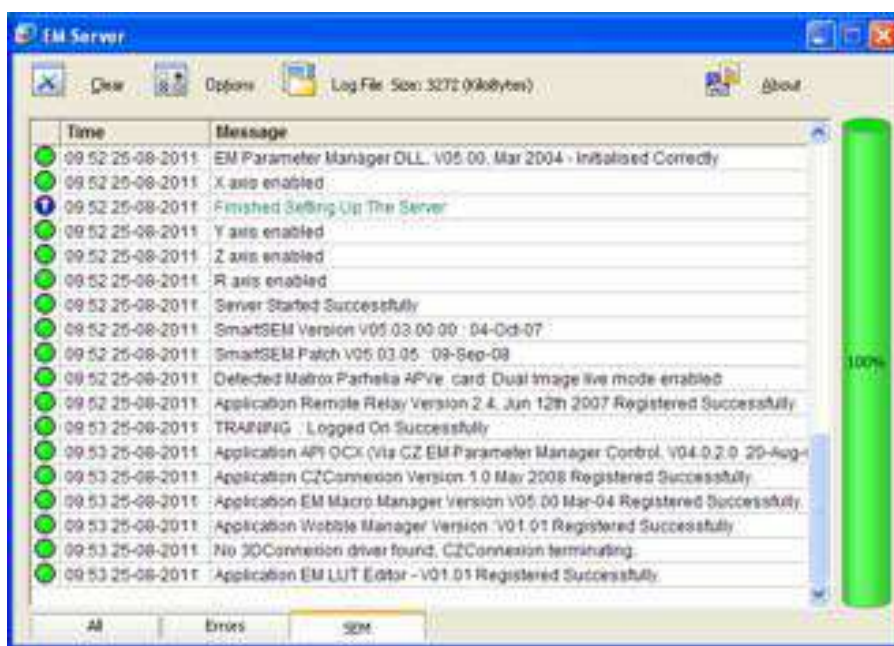


Figure 7 EM server window

- At this time a single Raith software window should be open. In order to turn on the SEM software



window, click on the Column Control icon. By default, the Raith software will load in the right screen and the SEM software will load in the left screen.



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6. In order to begin the loading process, enable the Raith window. Click on the **Load Lock** icon followed by the **Load Sample** button in the right hand vertical panel as shown in Fig. 8. There are a number of important icons on this panel whose names can be revealed by mouse over.



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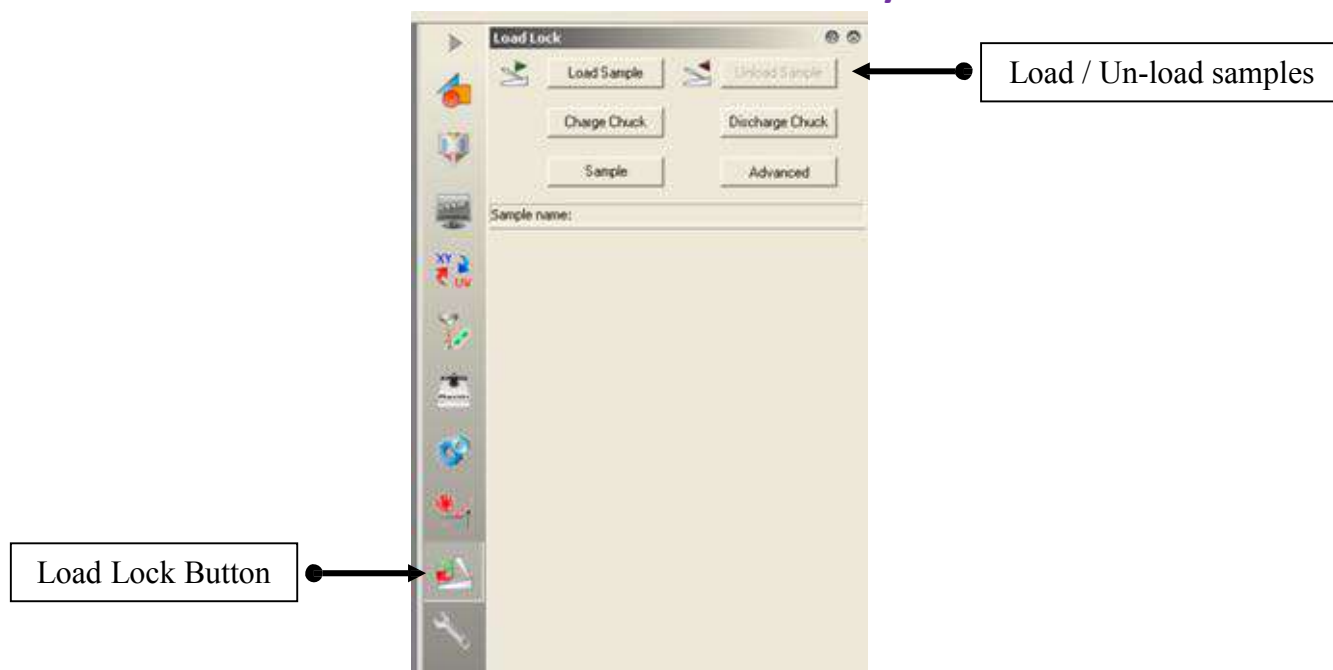


Figure 8 Loading / Un-loading samples

7. The loading process will begin. A window will pop-up as shown in Fig. 9(a) detailing the loading process. As a useful habit, track the movement of the sample holder by observing the **Coordinates** tab on the bottom right of the Raith window. The **Coordinates** tab is shown in Fig. 9(b).

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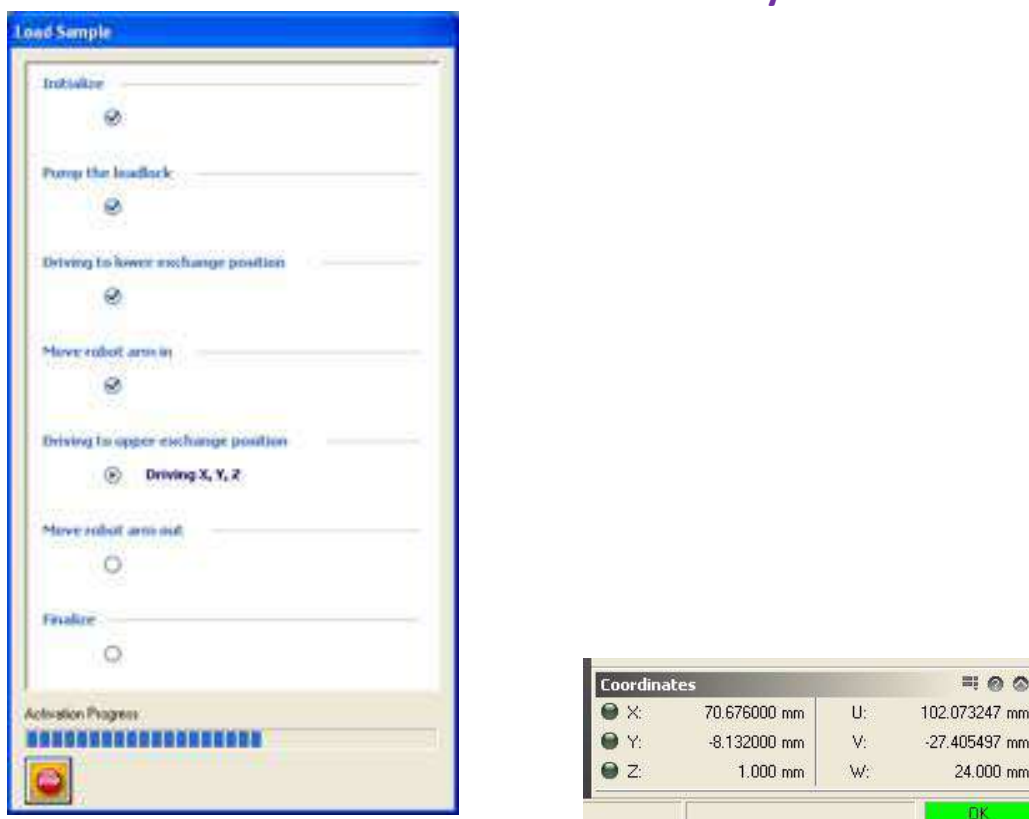


Figure 9(a) Sample loading details, and (b) Co-ordinates.

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8. After the loading process has completed, a number of pop-ups will prompt the user for action as shown in Fig. 10. Enter a **sample name** of your choice, press **OK**, press **OK**, and press **Yes**.



Figure 10 Pop-ups immediately after the sample loading process

9. At this stage, the sample holder will be visible in the SEM window as shown in Fig. 11.



Figure 11 SEM objective lens and sample holder as viewed by the chamber camera

10. After loading the sample holder, the stage should be raised to $Z = 19$ mm as shown in Fig. 12. To drive to your chip, you may either (i) input the XY co-ordinates if known, or (ii) navigate using the joystick. In addition, make sure the **mm**, **XY**, and **absolute** dialog buttons are selected as shown.

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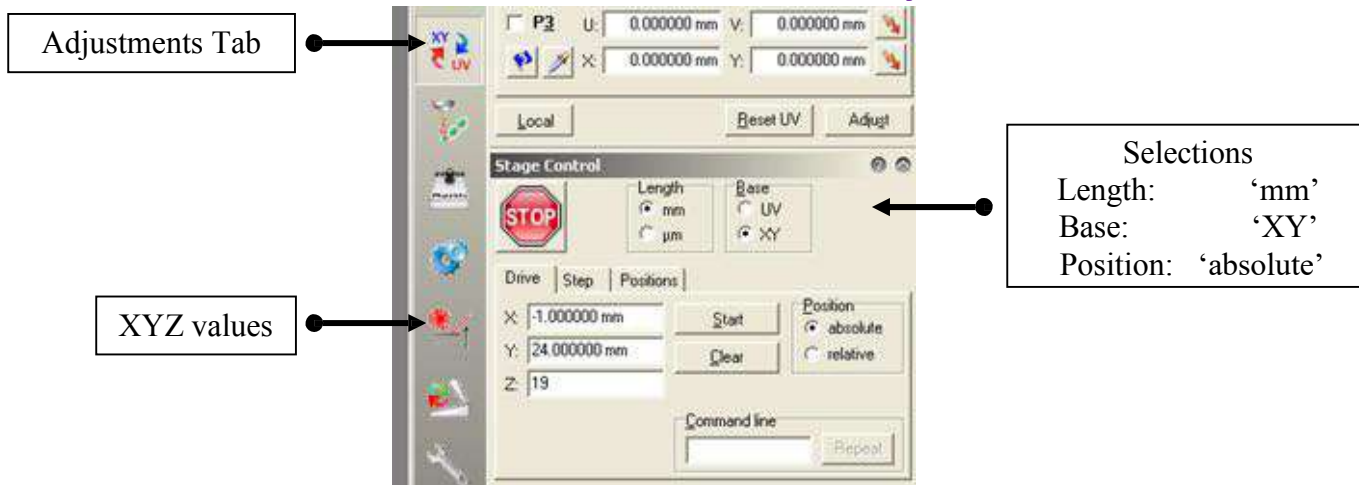


Figure 12 Raising stage and driving to sample position using Stage Control

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11. In order to turn on the column voltage (EHT), select the **Column Control** tab on the right panel, and activate the desired setting as shown in Fig. 13(a). A window will pop-up detailing the column initialization details as shown in Fig. 13(b). This process will take a few minutes; however, it should not take longer than 5 minutes for any voltage setting.

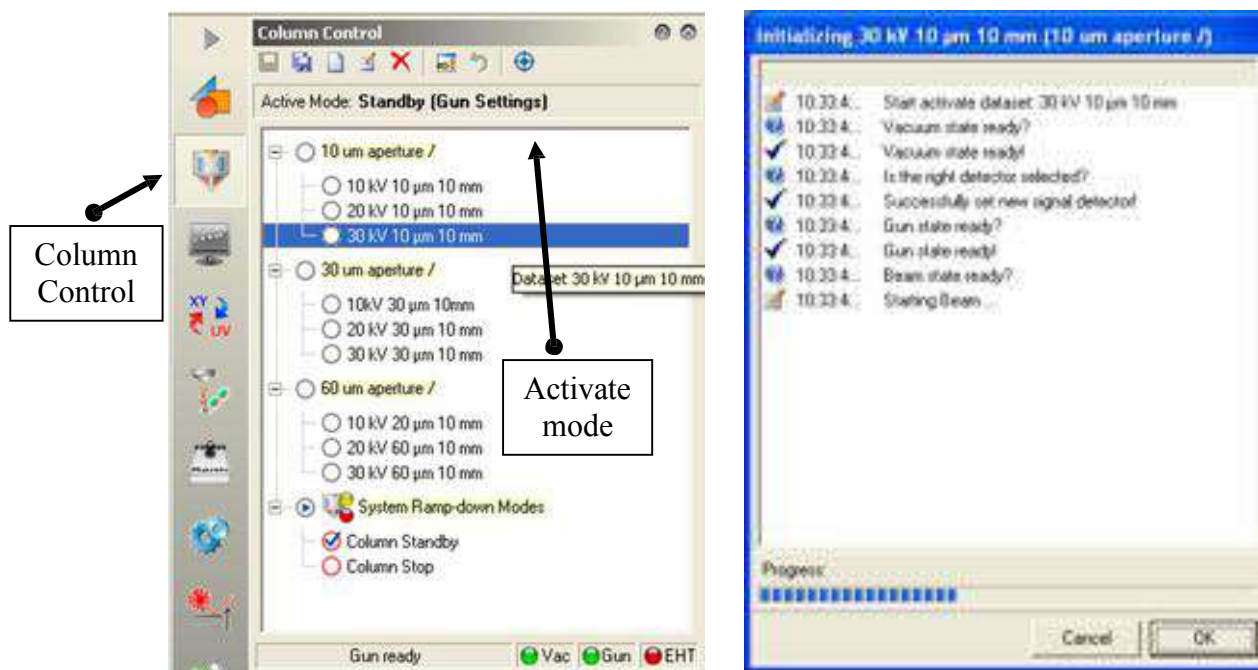


Figure 13 Turning on the column voltage (a) using Column Control, and (b) column initialization details

12. At this point, the SEM window will show the updated position of the stage with respect to the objective lens, and other column data as shown in the white data zone at the bottom of the camera image (Fig. 14). Clicking on the various parameters in the data zone (e.g., magnification, voltage, working distance etc) allows the user to change values. These values can be changed using the SEM software controls as well.

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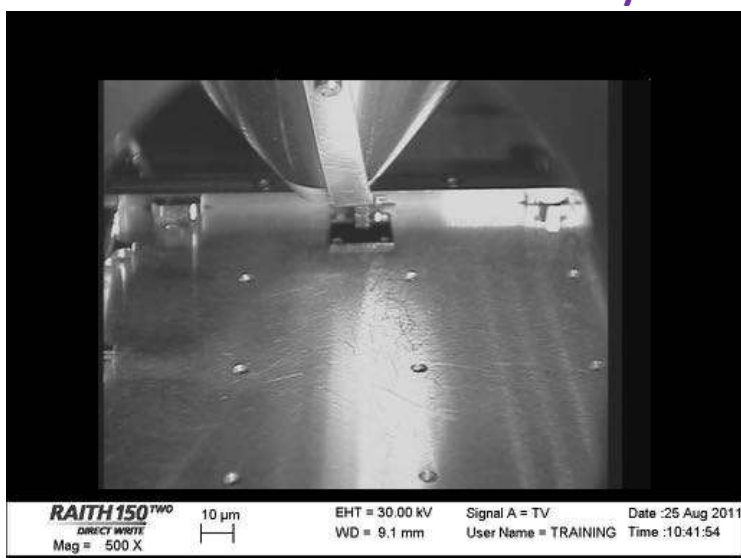


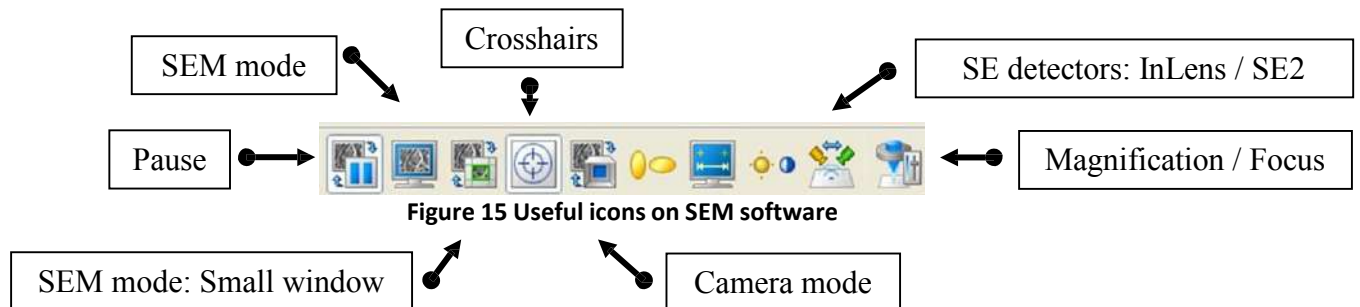


Figure 14 Camera image of the chamber with sample loaded and column on

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13. To switch from camera mode to SEM mode and begin imaging the loaded sample, the user must (i) enable the SEM mode  in the SEM software, and (ii) un-blank the beam  in the Raith software. Some other useful icons are noted in Fig. 15.



14. To perform origin correction and sample alignment, obtain a **rough focus** on the sample. **Zoom** in to 500X magnification and **centre the crosshairs** on the bottom left corner of the sample (Fig. 16).

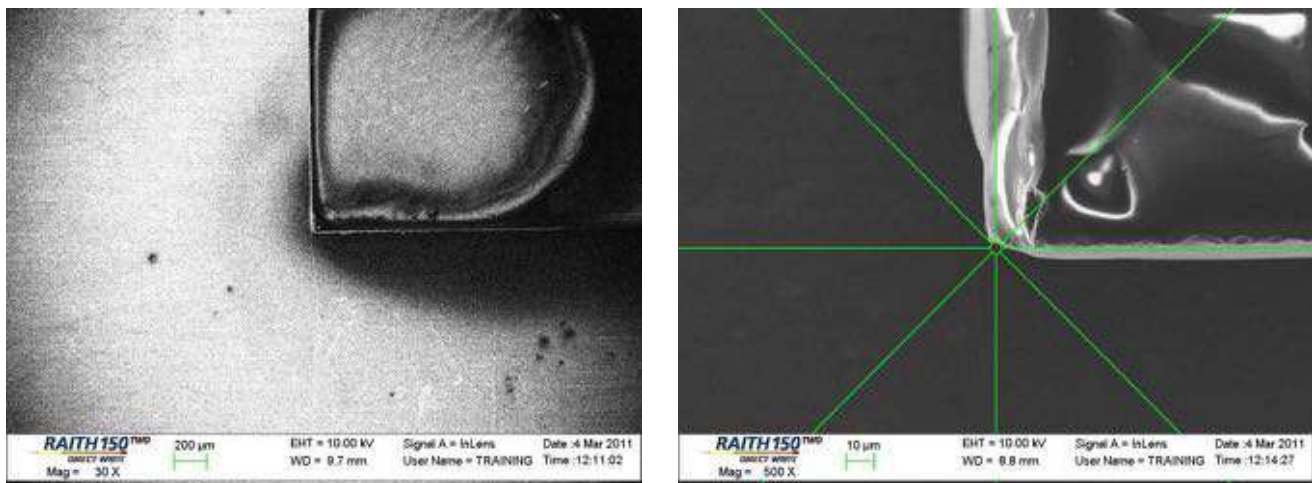


Figure 16 (a) Rough focus on sample, and (b) centering crosshair on bottom left corner at 500X magnification

15. In the Raith software, click on the **Adjustments** tab, ensure **Global** co-ordinates are selected, select **Origin Correction**, and click **Adjust** as shown in Fig. 17. Current X,Y position is now U,V = 0,0.

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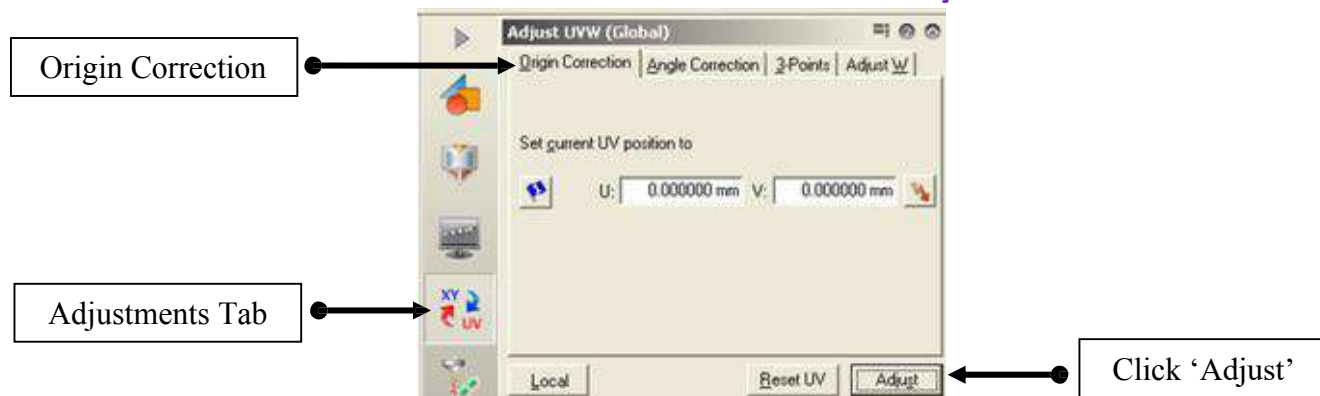


Figure 17 Origin correction in Adjustments tab

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16. While remaining at the origin (U,V = 0,0), select the **Angle Correction** tab, and click on the dropper



icon below **P1** (point 1). The XY values corresponding to point 1 will be loaded. Using the **joystick** move to the bottom right corner of the loaded chip. Centre the crosshairs onto the edge and click on the dropper icon below **P2** (point 2). The angle correction is finalized when the **Adjust** button is pressed (confirm color change of the **Calculated angle** value from red to green). See Fig. 18 for more details. **Note (Optional):** If the dimensions of the chip are known, stage movements can be performed by using the **Stage Control** tab. Simply input the dimension of interest and click **Start**. The beam will be blanked and the stage will accurately move to the desired location. Be cautious of selecting **mm**, **UV**, and **absolute**. Press **Clear** to reset form.

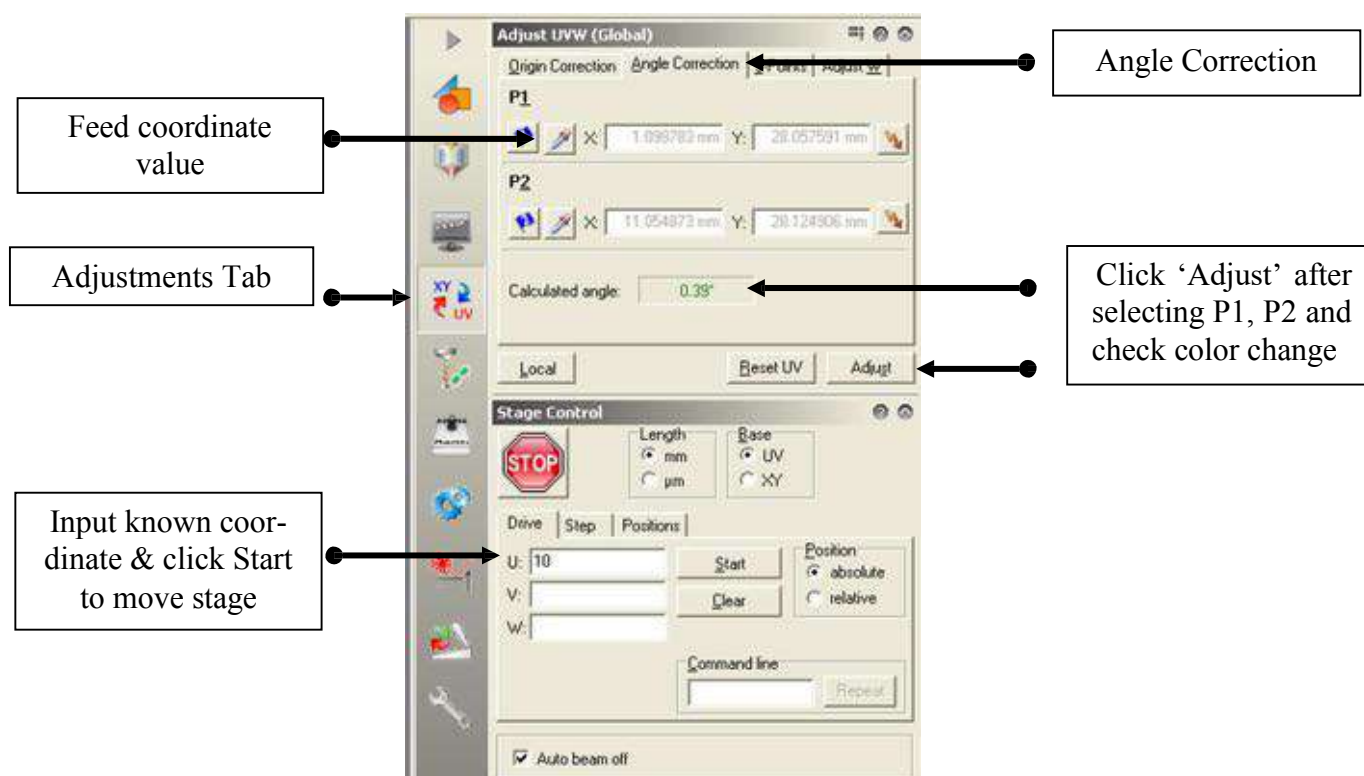


Figure 18 Angle correction in Adjustments tab

17. Find a particle of interest (approx. 200 – 300 nm wide) to perform column corrections namely focus, aperture alignment, and stigmation. These column corrections may be performed using either the Raith software (Fig. 19) or the SEM software (Fig. 20). A suggested sequence of action is provided:

- Obtain good focus using the selected particle.
- Perform aperture alignment – Test: particle should focus/defocus (*wobble*) without any lateral movement.
- Perform stigmation correction – Test (1): particle shape should not skew upon changing



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focus, and (2) contamination dot should be circular (more on this ahead).

- Iterate the above steps for improved results.

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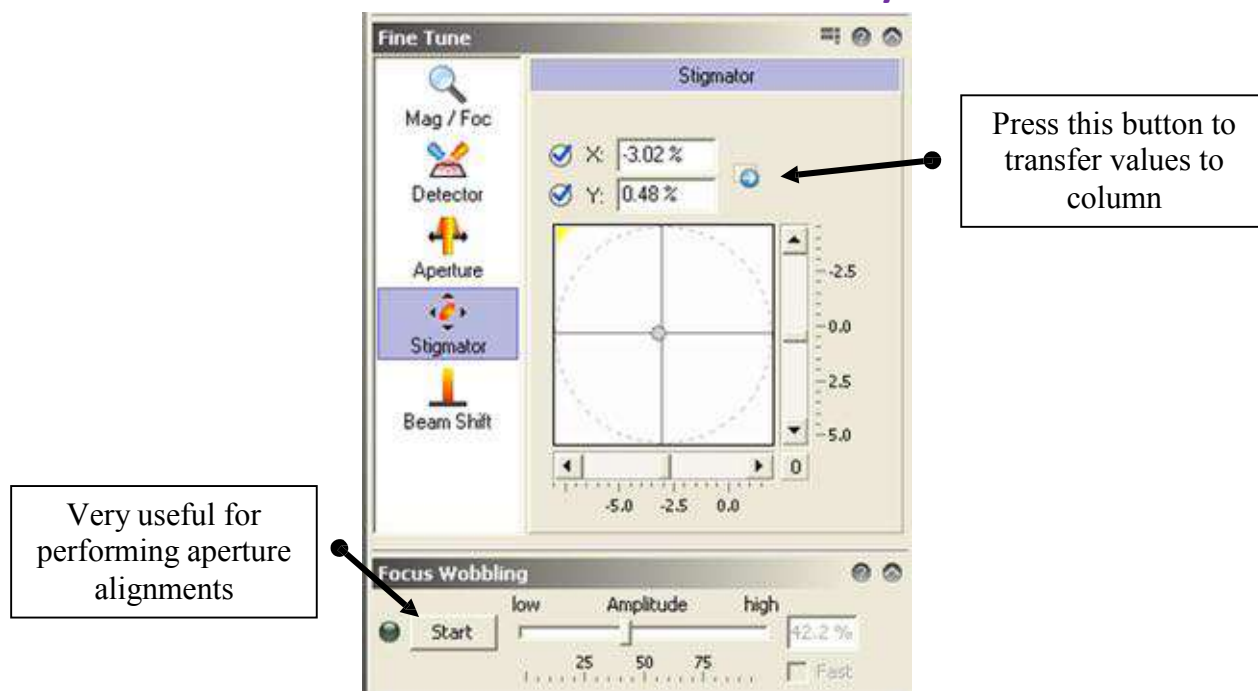


Figure 19 Column adjustments in Column Control tab in the Raith software

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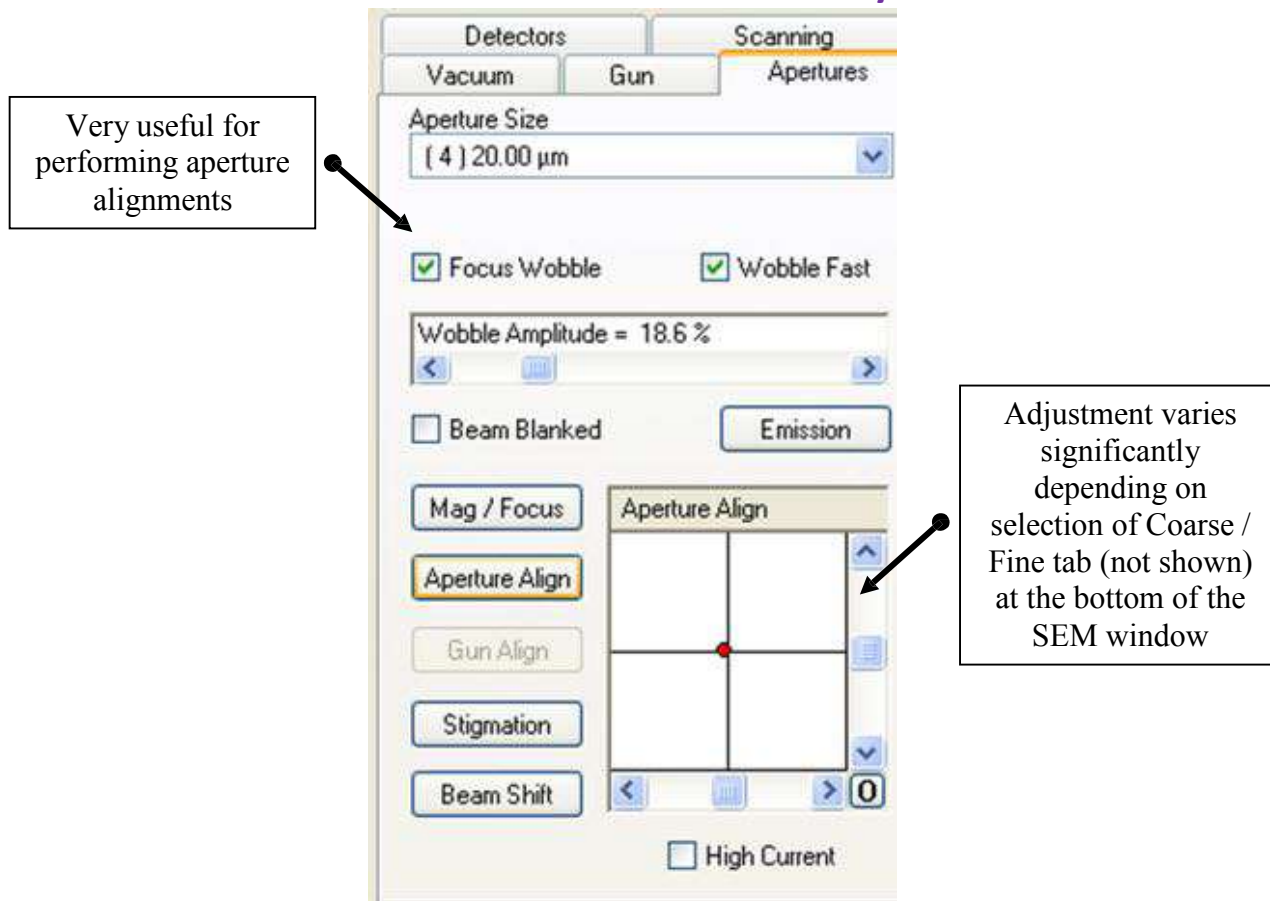


Figure 20 Apertures tab in the SEM software

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18. A very valuable test of the quality of column/focus corrections performed is burning a contamination dot. In this process, the user enables the **spot mode** for a certain duration. In the **spot mode**, the beam is un-blanked; however, the sample (resist) is not imaged for the duration of the burn process. Immediately after the **spot mode** duration is over, the sample is imaged to assess the quality of the contamination dot. Suggested steps:

- In the SEM window, enable the SEM mode (small screen)
 - Zoom in until the scale bar is approx. 100 nm wide
 - Blank the beam (Raith window)
 - Move to a location previously not imaged
 - Click the spot mode button in the SEM window. As soon as the spot mode button is clicked, un-blank the beam in the Raith window. Spot will appear shortly.
 - If the spot is not circular (see Fig. 21), perform column/focus corrections and iterate.
- Note 1: Clicking the left button (spot mode) yields a 3 second burn and clicking the middle button yields an indefinite burn (disabled upon re-clicking the middle button).
 - Note 2: After a certain level of proficiency is reached, the beam may not be blanked in order to burn a contamination dot.

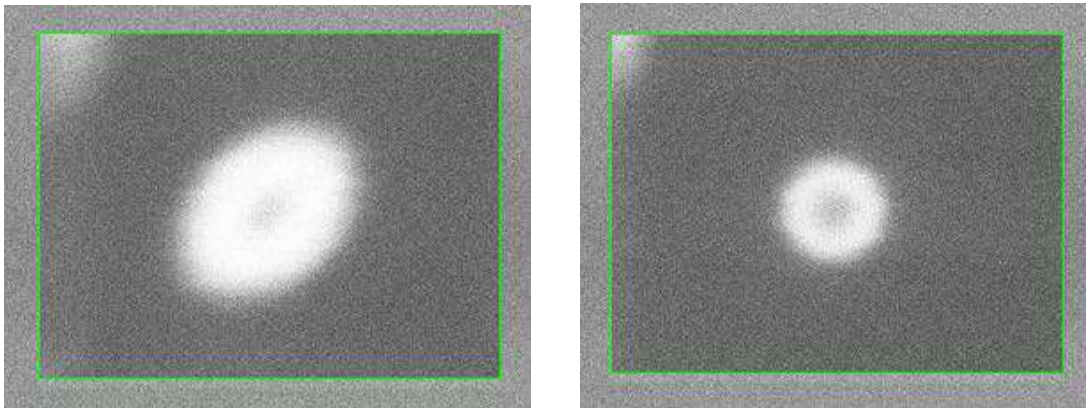


Figure 21 (left) Contamination dot with astigmatism, and (right) optimized 30 nm diameter contamination dot

19. Select a particle or a contamination dot of interest to perform writefield (WF) alignments. Centre the SEM crosshairs on the object and select the magnification and WF size as shown in Fig. 22.



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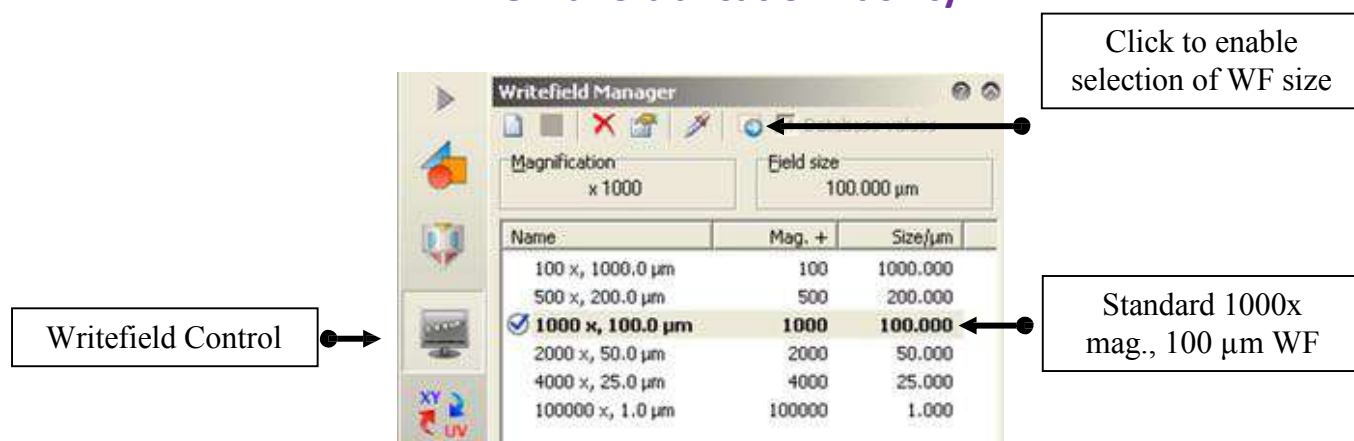


Figure 22 Writefield Manager tab in Writefield Control menu in the Raith window

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20. In the Raith software, click on **File >> New Image** to open an empty pop-up window.



21. In the Raith software, click on the **Single Scan** icon. Note that the scanning has stopped in the SEM window. The column control has been taken over by the Raith software. The pop-up window from the previous step is now filled with a single scan of the imaging area from the SEM software.

22. In the Raith software, click on the **Writefield Control** menu, minimize the **Writefield Manager** window, and enable the **Scan Manager** window. In the current window, select **Writefield Alignment Procedures >> Manual >> 100 um WF – Manual ALWF 25 um marks >> right click >> Execute** as shown in Fig. 23.

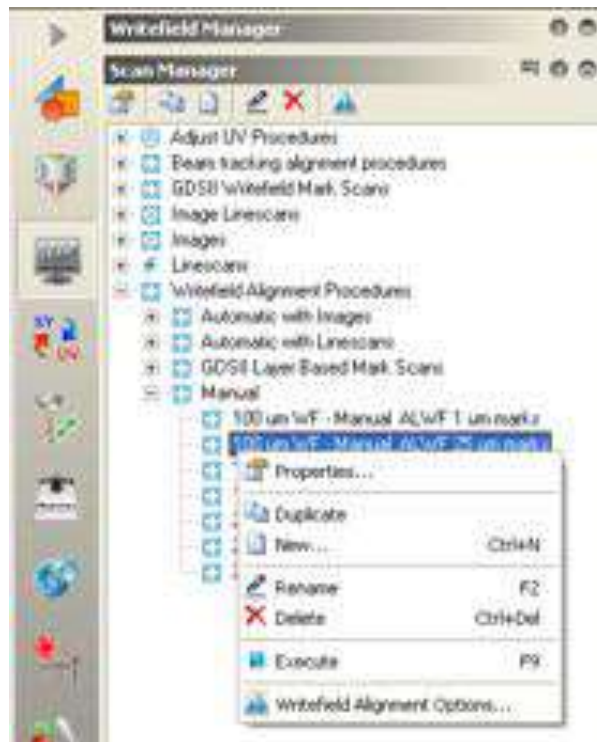


Figure 23 Scan Manager tab in the Writefield Control menu in the Raith window

23. The pop-up window from steps 20-21 will refresh and a crosshair and various boxes will appear on the window (Fig. 24(a)). The user is supposed to select a location of interest, hold down the **Ctrl** key and drag the crosshair onto the *exact same location of interest* three or more times. Each time a pop-up window (Fig. 24(b)) will prompt the user to confirm accuracy of crosshair alignment.

24. After each alignment procedure is completed, a pop-up will appear (Fig. 25) prompting the user to confirm WF correction values. The target is to eventually get **Zoom U** and **Zoom V** values to read four zeros or four nines after the decimal place. After the first WF correction is completed, select **100 um**



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WF – Manual ALWF 5 um marks and perform the steps described in step 23 above, followed by **100 um WF – Manual ALWF 1 um marks** to sequentially improve the accuracy of the WF correction.

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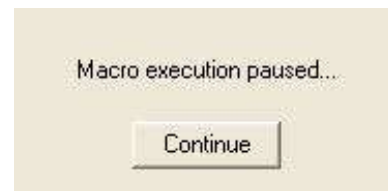
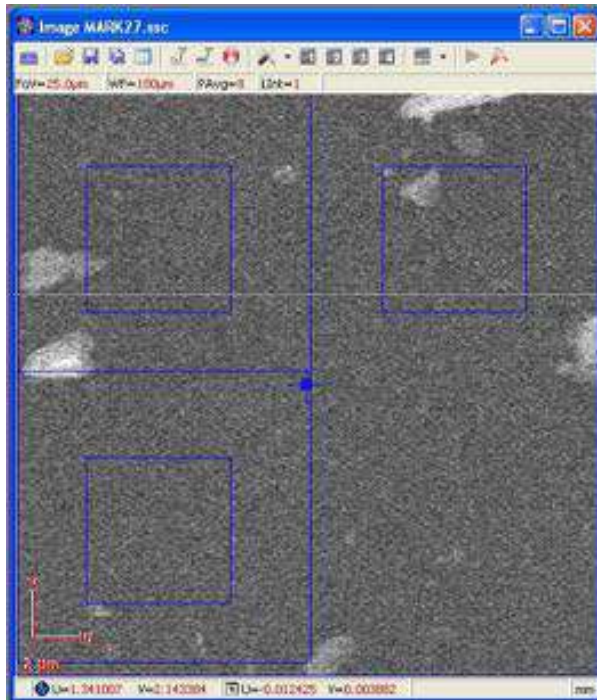


Figure 24 (a) Writefield alignment procedure window, and (b) user prompt to confirm crosshair alignment



Figure 25 Writefield correction values

25. As an optional further correction, the user may choose to perform an automatic WF correction. In the Scan Manager window, select **Writefield Alignment Procedures >> Automatic with Images >> 100 um WF – Auto ALWF 1 um marks >> right click >> Execute** after the last manual WF alignment has been



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performed. This will begin an automatic WF alignment procedure. The correction values will not be available in a pop-up window this time. For confirming whether the system has improved the WF correction values, open the **Raith Protocol Tool** window >> **WF alignments**. Notice that the zoom factors have improved over the previous step (latest alignment listed first) in Fig. 26.

The screenshot shows the Raith Protocol Tool interface. At the top, there is a menu bar with 'File', 'View', and 'Tools'. Below the menu bar, there are input fields for 'Date' (8/25/2011), 'User' (All user), and 'Sample' (All samples). Below these fields, there are several buttons: 'Reset', 'Program Data', 'File Name', 'Refining', 'WF Adjustment', 'Zoom Setting', 'UV Adjustment', 'Soft Compensation', 'Soft Zoom Area', and 'Volume Map'. The main part of the interface is a table with 13 columns: 'Time', 'User', 'Sample', 'WF size (µm)', 'Mag.', 'WD (mm)', 'EHT (kV)', 'Factor zoom U', 'Factor zoom V', 'Delta shift U (µm)', 'Delta shift V (µm)', 'Delta rot. U (deg)', and 'Delta rot. V (deg)'. The table contains 5 rows of data, all for the user 'mnohammad' and sample '2011_08_25_PPMA_1'.

Time	User	Sample	WF size (µm)	Mag.	WD (mm)	EHT (kV)	Factor zoom U	Factor zoom V	Delta shift U (µm)	Delta shift V (µm)	Delta rot. U (deg)	Delta rot. V (deg)
11:30:09	mnohammad	2011_08_25_PPMA_1	100	1000	8.89022430	0.99999	0.99992	0.003	0.004	0.000	-0.004	
11:29:50	mnohammad	2011_08_25_PPMA_1	100	1000	8.89022430	0.99985	1.00030	-0.024	0.010	0.009	0.008	
11:29:19	mnohammad	2011_08_25_PPMA_1	100	1000	8.89022430	1.00049	0.99950	0.284	-0.002	-0.009	-0.003	
11:28:51	mnohammad	2011_08_25_PPMA_1	100	1000	8.89022430	0.99999	1.00012	-0.858	-0.252	0.000	-0.003	
11:28:14	mnohammad	2011_08_25_PPMA_1	100	1000	8.89022430	1.04477	1.06032	10.985	-2.417	0.002	-0.002	

Figure 26 WF correction values shown in the Raith Protocol Tool

26. At this stage, all the corrections have completed. It is time to measure the beam current and proceed with the exposure. To measure the beam current, drive to the Faraday cup (a small device used to measure small current quantities) as shown in Fig. 27(a). The orifice of the Faraday cup is shown Fig. 27(b).

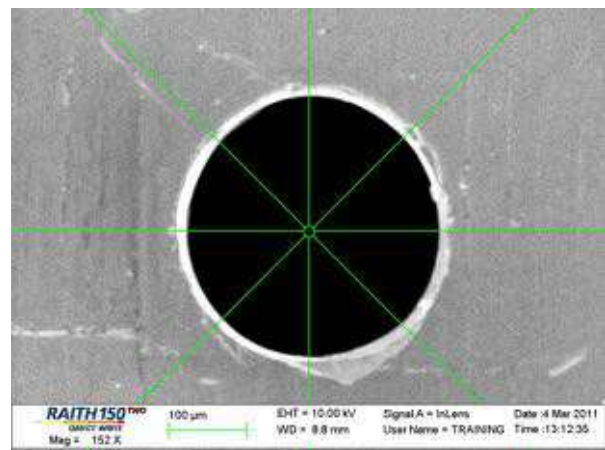



Figure 27 (a) Stage Control (Positions tab) window in the Adjustments menu, (b) Faraday cup orifice.


27. Ensure that the crosshairs of the SEM image are well centered on the Faraday cup. Zoom in (preferably all the way) until the opening of the Faraday cup cannot be seen (unlike Fig. 27(b) above). This is to ensure that all the electrons are collected by the Faraday cup and the system reads a proper current

value. In the Raith software right menu bar, select the **Exposure** icon  and enable the **Beam Current** window. Select **<current position>** in the drop down menu and click **Measure**. The current will be displayed in the selected units as shown in Fig. 28.

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Figure 28 Beam Current measurement window in Exposure menu

28. In the Raith software, select the **Design** icon  and enable the **GDSII Database** window. Open the **Demo.csf** file from your home directory. Your home directory will also have a couple of documents (provided by Raith GmbH) that describe the demo pattern in detail. Please read these documents.

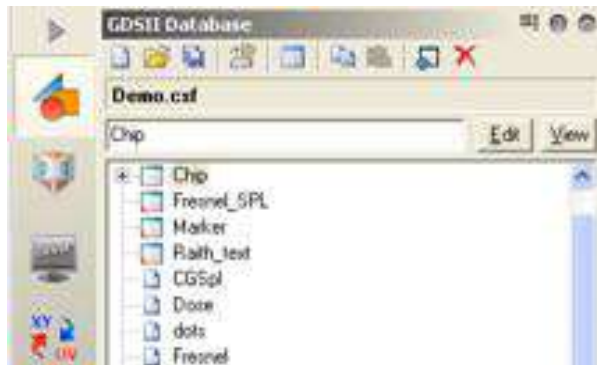


Figure 29 Open GDSII database files in the Design menu


29. Select the **Exposure** icon  and enable the **Exposure Parameter** window (Fig. 30).



Figure 38 Exposure Parameter window in Exposure menu

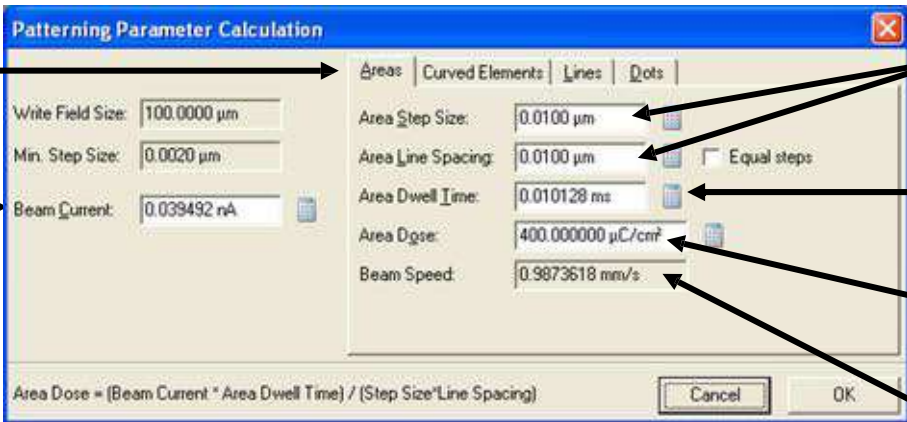
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30. Refer to Fig. 30. Click the **layers** button from the **Exposure Parameter** window. A window (Fig. 31) will pop-up which allows the user to select which layers are to be exposed. It is better to select the layers manually; however, for custom patterns known to the user, the **Used** button may be clicked to select multiple layers simultaneously. Press **OK** when done.



Figure 31 Select layers for exposure

31. Refer to Fig. 30. Click the **exposure parameter calculator** icon. A window (Fig. 32) will pop-up allowing the user to input various parameters. For *your* process, please ask your trainer/colleagues for sample values or consult the various manuals on the **NanoFab website >> Resource Library**. As a broad guideline, ensure that **Step Sizes** and **Beam Speed** do not exceed 20 nm and 10 mm/s respectively. Optimal values for both parameters may be significantly lower depending on *your* process.



The image shows a 'Patterning Parameter Calculation' dialog box with the following fields and annotations:

- Update all tabs!**: Points to the 'Areas' tab.
- Pre-loaded**: Points to the 'Beam Current' field.
- User Input**: Points to the 'Area Step Size' field.
- Click Calculator Icon**: Points to the calculator icon next to the 'Area Dwell Time' field.
- User Input**: Points to the 'Area Dose' field.
- Verify < 10 mm/s**: Points to the 'Beam Speed' field.

The dialog box contains the following fields and values:

- Write Field Size: 100.0000 μm
- Min. Step Size: 0.0020 μm
- Beam Current: 0.039492 nA
- Area Step Size: 0.0100 μm
- Area Line Spacing: 0.0100 μm
- Area Dwell Time: 0.010128 ms
- Area Dose: 400.000000 $\mu\text{C}/\text{cm}^2$
- Beam Speed: 0.9873618 mm/s

At the bottom, the formula is displayed: $\text{Area Dose} = (\text{Beam Current} * \text{Area Dwell Time}) / (\text{Step Size} * \text{Line Spacing})$. Buttons for 'Cancel' and 'OK' are at the bottom right.

Figure 32 Exposure parameter calculator (example values only!)

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32. In the Raith software, click on **File >> New Positionlist**. A window will pop-up (Fig. 33) in the Raith software. Drag and drop your design (.csf) files from the **Design** menu (**GDSII Database** window) into the positionlist. You may input multiple designs in the positionlist. **Right click** anywhere on the inserted file information bar and click **Properties**. A window (Fig. 34) will pop-up. Insert values as shown.

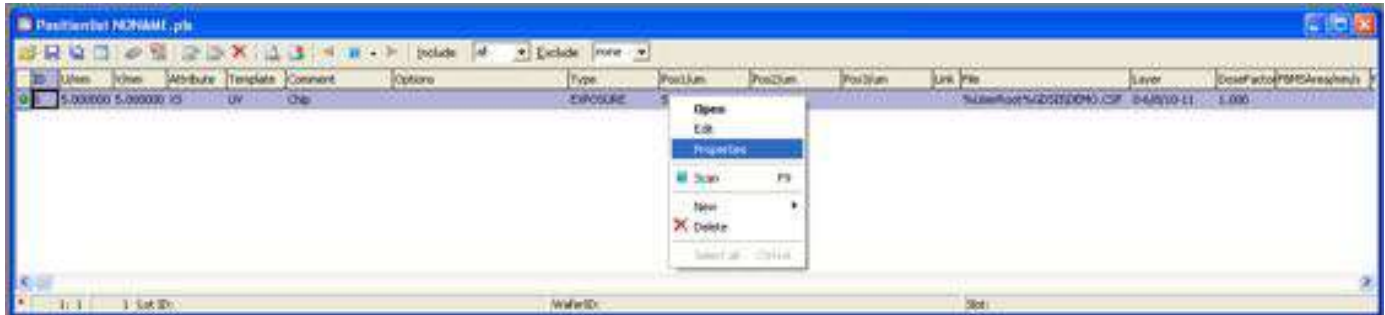


Figure 33 Positionlist setup for exposure

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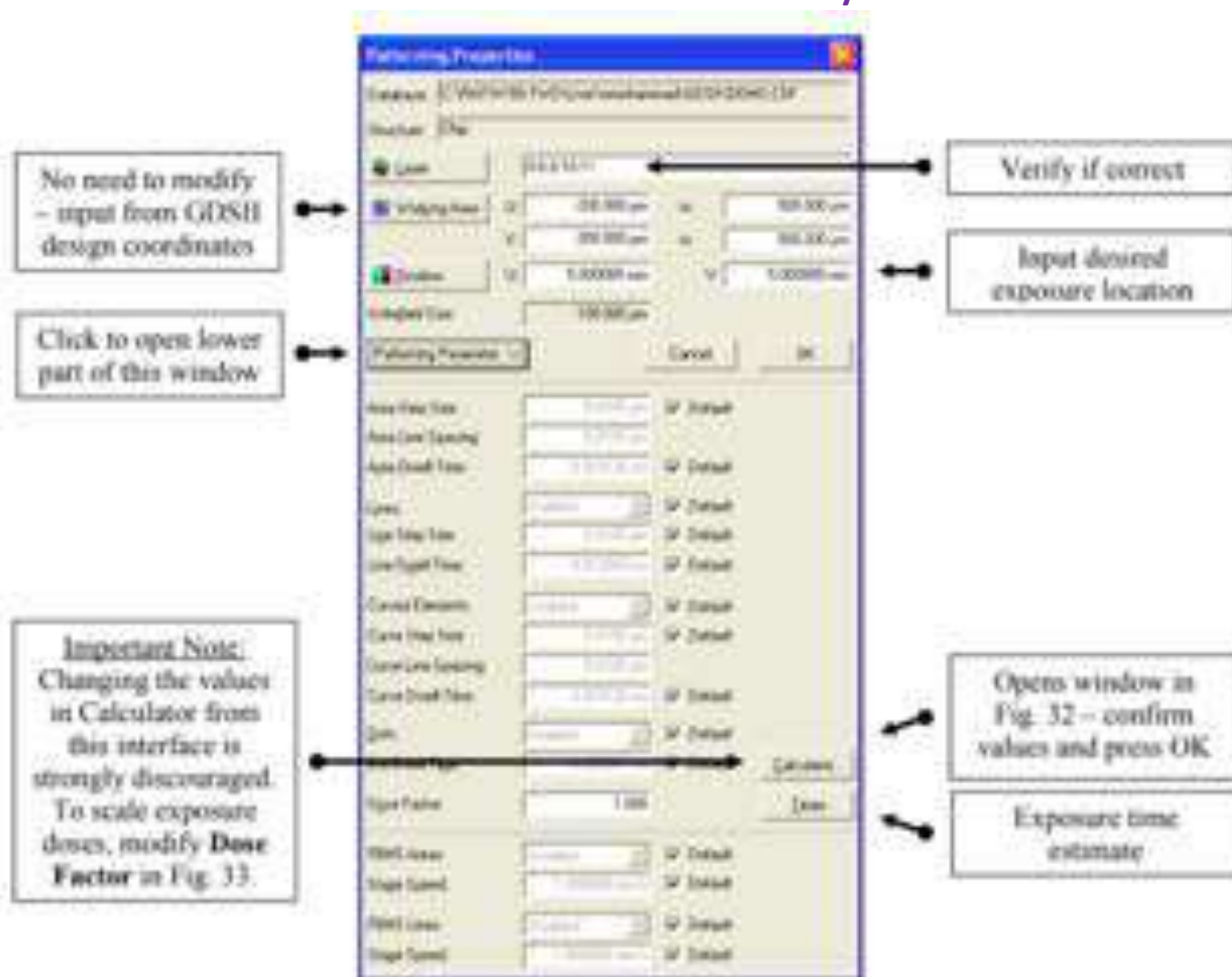


Figure J4 Patterning properties window



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33. Prior to exposure, the following necessary precautions must be taken:
 - Ensure the joystick is turned off.
 - Ensure the beam is blanked in the Raith software.
 - Ensure the usage of SEM mode in the SEM software (i.e., not chamber camera mode).
34. To begin exposure, enable the Raith software, click **Scan >> All** in the top level menu. Alternatively, enable the positionlist, **right click** on the file information bar (Fig. 33) and click **Scan**. A window will pop-up which will show the exposure progress to the user. Once the exposure is complete, this window will disappear.
35. Unload sample as described in step 6 (Fig. 8), except click **Unload Sample** this time. The **Load Sample** icon will be disabled. The unloading process will take approximately five minutes.
36. Close the Raith software followed by the SEM software. **Log Off** the **EM Server** when prompted.
37. Remove your sample, fill in the log-book, and clean up the computer area before leaving.

5. TROUBLESHOOTING

- ❖ If you encounter a black SEM screen after ramping up the voltage, (i) ensure the correct **detector** is used (see Fig. 15) as follows: **InLens** for 0.1 – 20 keV, and **SE2** for 20 – 30 keV, (ii) ensure the **Emission** mode is not selected (see Fig. 20), and (iii) correct **brightness/contrast** levels are used.
- ❖ If the system fails to load the sample holder after 10 minutes or more, restart the Raith software and try again. If met with failure two consecutive times, please phone the designated staff member and/or proceed with the error reporting procedure as outlined in the notice beside the Raith computers.
- ❖ If the system fails to ramp-up to the desired voltage after waiting for 5 minutes or more, note down and clear any error/warning messages on the Raith software and try to ramp again. If the systems fails again, restart the Raith software and attempt ramping again. If met with failure two consecutive times, please phone the designated staff member and/or proceed with the error reporting procedure as outlined in the notice beside the Raith computers.

Error reporting guidelines are posted on the wall beside the Raith 150^{TWO} computers. This document defines what to do in various emergency situations. For processing issues and more information, please contact nanofab-cleanroom@nyu.edu



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6. References

https://www.nanofab.ualberta.ca/wp-content/uploads/downloads/2011/09/Raith_150TWO_SOP.pdf