

RAITH

NANO FABRICATION

Raith NanoSuite Tutorials



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Structure of Tutorials

The Tutorials are structured into different Tasks, each task consists of several Steps. Each tutorial has an aim specified at the start of each tutorial, and the tasks will guide you step-by-step through the process of achieving this aim. To set up an exposure you will need to carry out the tutorials 1-4 first before performing the exposure in tutorial 5. It is important to study the tutorials in the given order. Tutorial 6 gives an overview of general pattern designs.

The SEM portion of the system is referred to as the Column Control. The Raith portion of the system is referred to as the Lithography Control.

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Raith Tutorial-1: Getting Started

AIM

The aim of this tutorial is to familiarize the user with the basic functions of your Raith EBL system. The first task is to switch the system on, load the sample and to obtain an SEM image of your sample.

As the starting point for this tutorial it is assumed that the system is already switched on, but nobody has logged in.

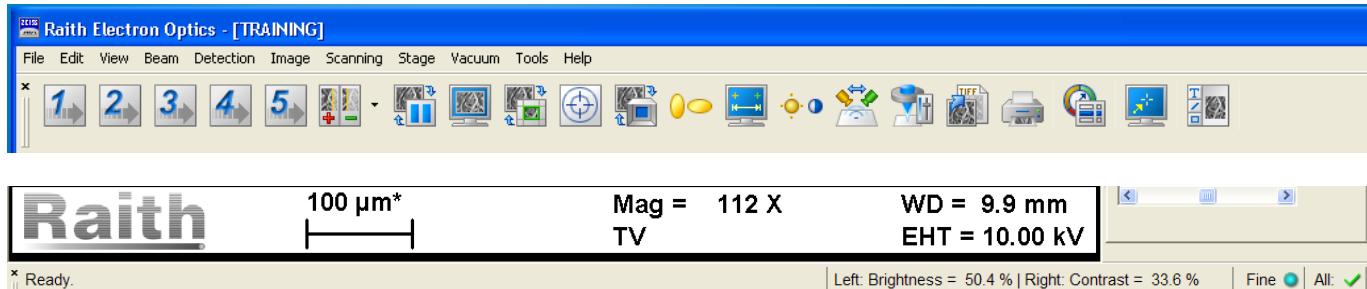
HINT If the system has been left in another status, i.e. switched off completely, please contact a specialist for advice. For the operation of the Raith system, both the column and lithography software have to be installed and running. In addition, there must be communication between the column and lithography software.

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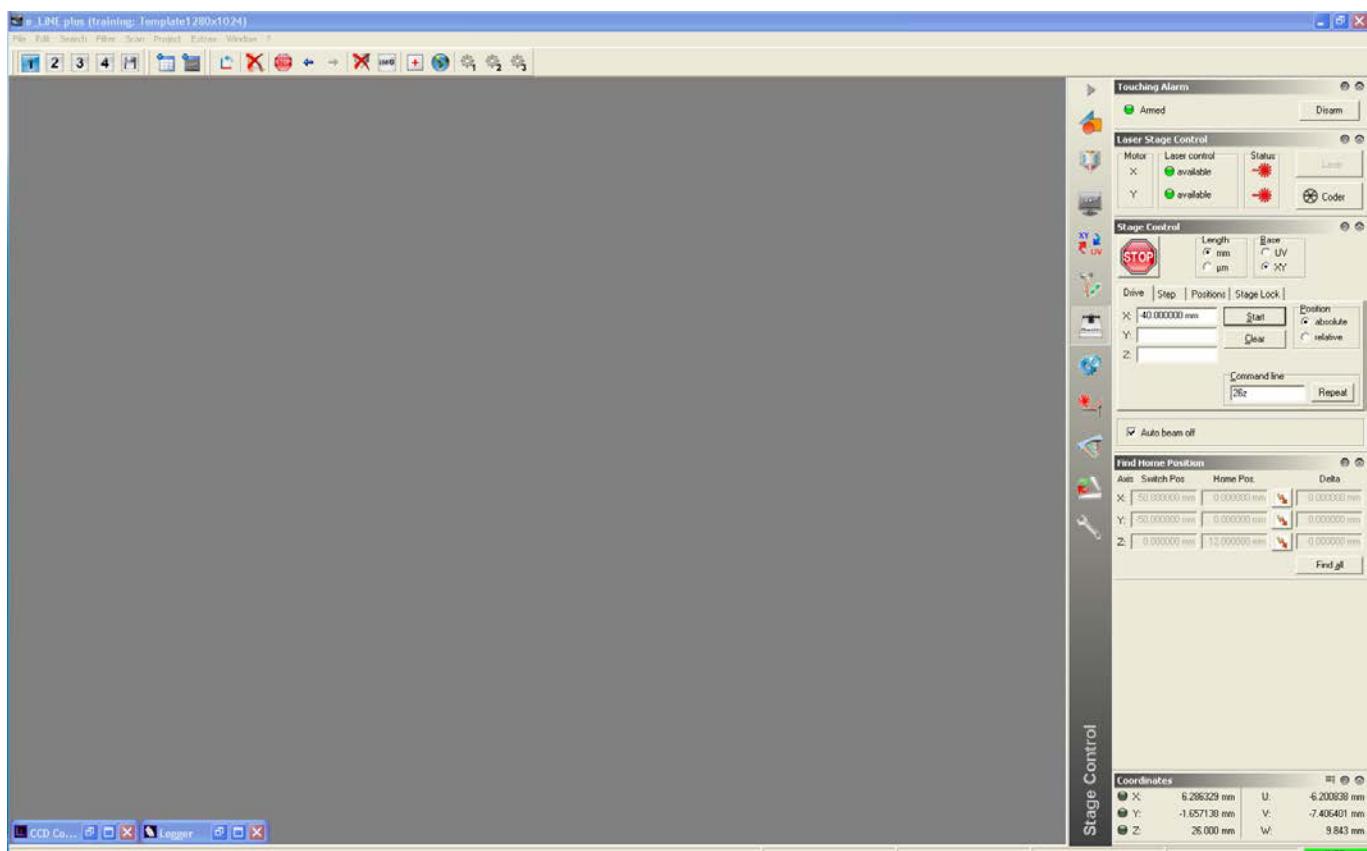
TASK 1: Start the system

- STEP 1** Start the column software and log in as user “training”, password “training”.

The column desktop displays the operation icons at the top and the image information as well as the status controls at the bottom of the screen.



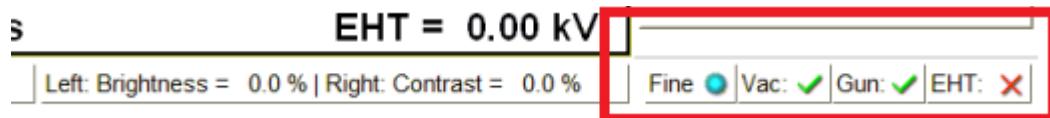
- STEP 2** Start the lithography software and log in as user “training”, password “training”. The Figure below shows a typical desktop display.



- STEP 3** Check if the lithography software has control over the column software by clicking at the IMG icon in the lithography desktop. The icon has two modes; when showing “IMG”, the column is controlled through the column software, i.e. a scan is running. In the other mode the icon will display “PAT”, in this case the column is controlled via the lithography software and the last scan will be frozen, therefore no running scans are shown.



STEP 4 Check for the status of the vacuum condition, shown in the lower right corner of the column software, to make sure the vacuum is OK. We assume that the gun is running (green tick) and that the acceleration voltage EHT is switched off (red cross).



The green ticks illustrate that the vacuum and gun conditions are OK (green tick). The red cross illustrates that the acceleration voltage is switched off.

HINT

The toggle between Coarse and Fine control is a most useful feature. The Coarse and Fine control is always correlated to the currently selected parameter, such as Focus, Brightness, Alignment etc. All parameters, which can be adjusted using the mouse, can be either performed in Coarse or Fine mouse control. They also scale with the set magnification.

TASK 2: Preparing a suitable sample

It is recommended that the sample should contain very small features suitable for imaging at high magnification with high contrast. For example, small metal particles can be added at the corner of a resist sample. Those particles will aid the SEM optimization which coincides automatically with the optimized beam conditions for exposure.

- STEP 1** Use a Q-Tip or a soft tissue and wipe over a used sputter target in order to collect small non-magnetic metal particles. A colloidal suspension can also be used, such as the polystyrene-latex sphere solution found in the EBL Starter kit.
- STEP 2** Now touch the new resist sample carefully at two opposite corners with the Q-Tip or the soft tissue, this will leave enough metal particles for the optimization method. Or dip a toothpick into the polystyrene solution and apply a small drop to the corners instead using the metal particles.

Although this method might not be professional enough for the experienced lithography level, it will be most useful for a novice to gain some experience.

TASK 3 Loading and unloading samples

HINT For this tutorial we would recommend a small sample, for example one square cm with electron beam sensitive resist, e.g. PMMA

STEP 1 We have to verify if a sample is loaded or not. To check this, use the CCD camera to view the inside of the vacuum chamber. Click on the Monitor icon in the columns desktop.



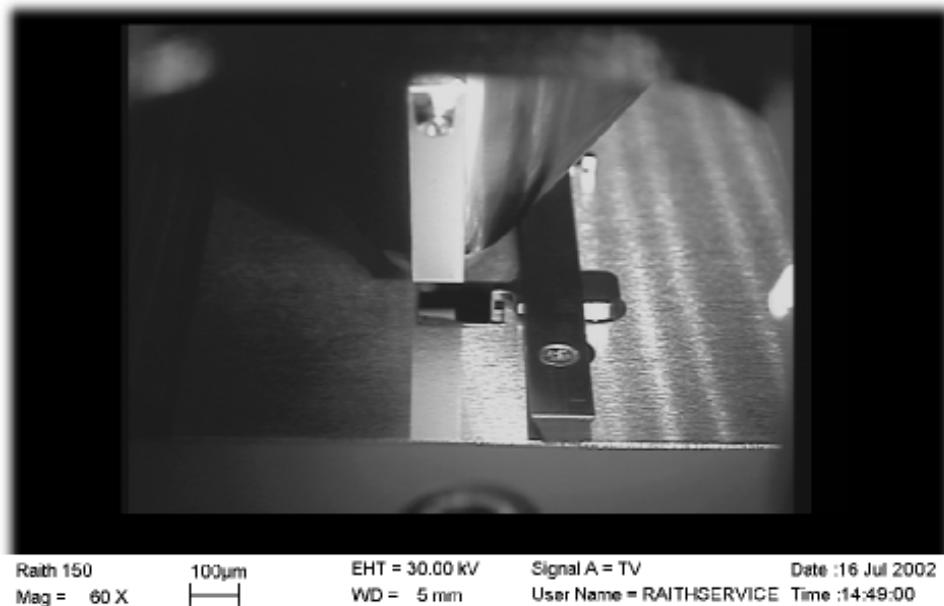
Click on the Monitor icon to view the chamber.

The CCD camera will now display a live image of the stage. An example is given in the figure below. The image shows the system with a sample holder inside the chamber.

A) In the case that the sample holder is within the chamber, you have to unload it. This procedure is described in Step 3.

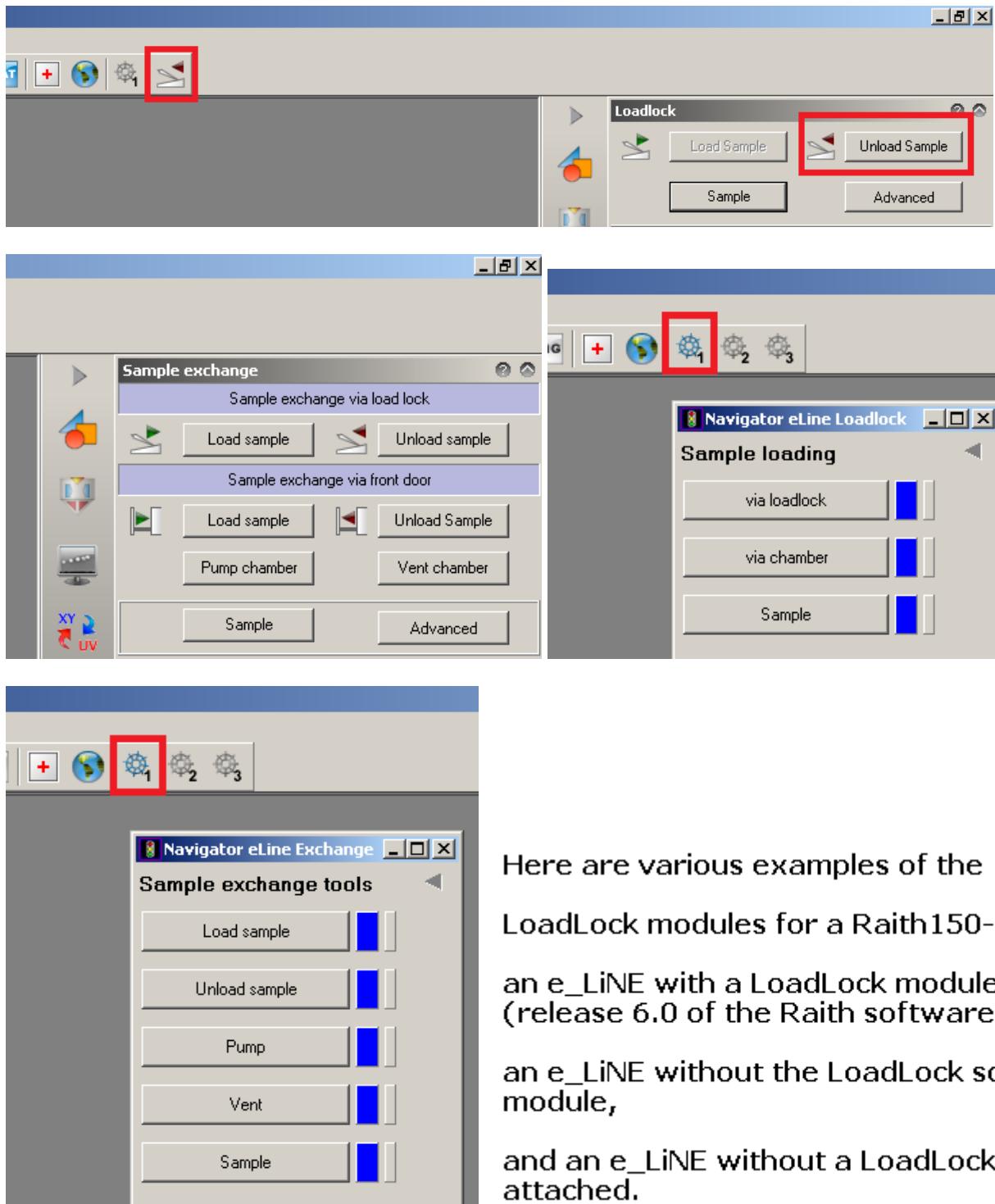
B) If there is no sample holder in the chamber, the following procedure will guide you to introduce one into the system:

Place the sample holder with your sample on the robot arm of the loadlock.



STEP 2 Check the current color of the traffic light icon number 1 in the lithography desktop. If it shows green, the Navigator Exchange is already open. Click on Sample Loading and then

on the Load Sample button. The loading operation is marked red if a sample is already loaded.



Here are various examples of the LoadLock modules for a Raith150-TWO, an e_LiNE with a LoadLock module, (release 6.0 of the Raith software) an e_LiNE without the LoadLock software module, and an e_LiNE without a LoadLock attached.

- STEP 3** At the end of the automated loading procedure the user will be prompted whether the system should switch on the beam. Accelerating voltage and aperture can be typed in by the user. You should start with 10 kV acceleration voltage and 30 nm aperture. The system asks whether to reset the coordinate system. It is safe to click okay.

To check whether the acceleration voltage is switched on, on the column desktop, there should be a green tick next to the EHT in the bottom right corner.

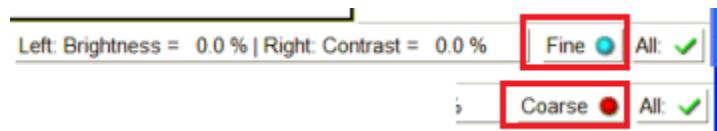
Check the home position. Use the lithography desktop, go to the Coordinates window and check if XYZ is displayed as zero.



TASK 4: Obtaining an SEM image

HINT

If the bottom line in the column desktop shows Fine (light blue), change it showing Coarse (red) by clicking on it once to widen the range available. At the start you might be a long way out of focus and you might therefore aim to see a noisy and medium white picture, which is neither totally black nor white. To obtain an image you need to adjust the column parameters as explained in the next steps.

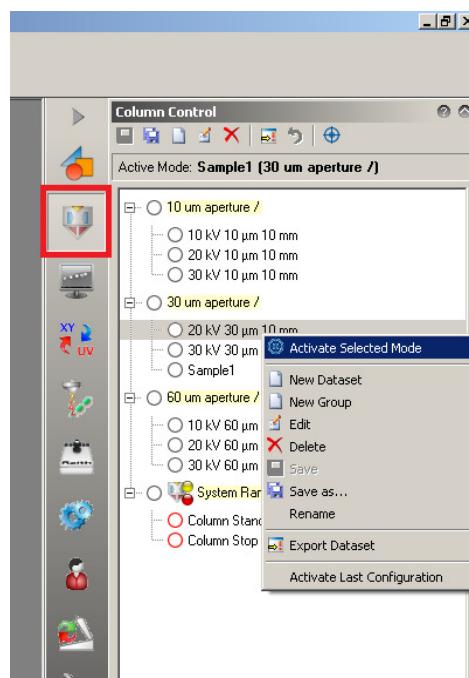


- STEP 1** Select Scan Speed '1' icon using the column desktop. A fast scan will be produced. During the fast scan, only some noise can be noticed as the acceleration voltage (EHT) is still switched off.

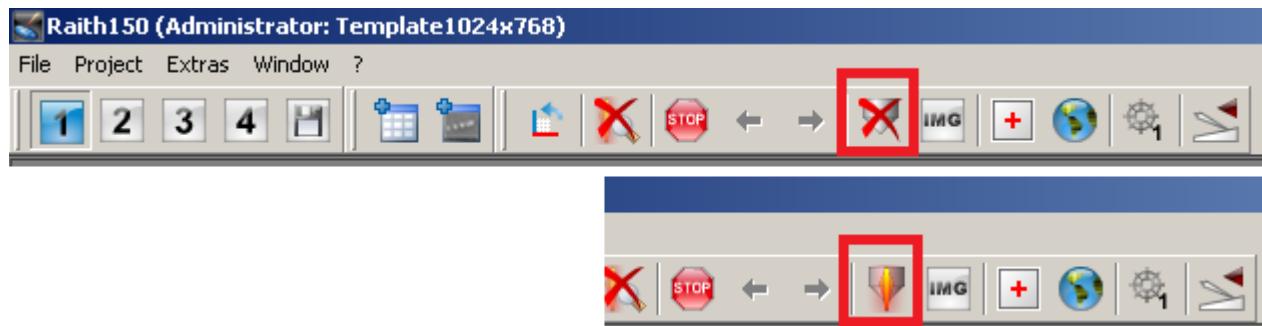


Click on scan speed '1' to obtain a fast scan

- STEP 2** The EHT will be switched on automatically during the sample loading. If you did not turn the EHT on after the load procedure, turn on the EHT using one of the Column Control settings in the Raith software.



- STEP 3** The beam blanker should be in the OFF state. In order to check this, click at the column icon left from the SEM icon in the lithography desktop and check if the beam blanker changes the signal during the scan. Leave the beam on.

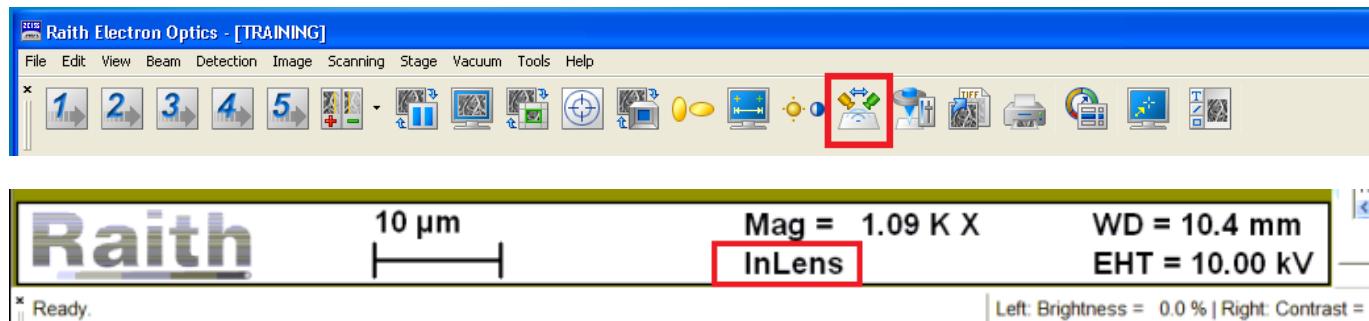


The beam is switched OFF/ON via the Beam Blanker icon

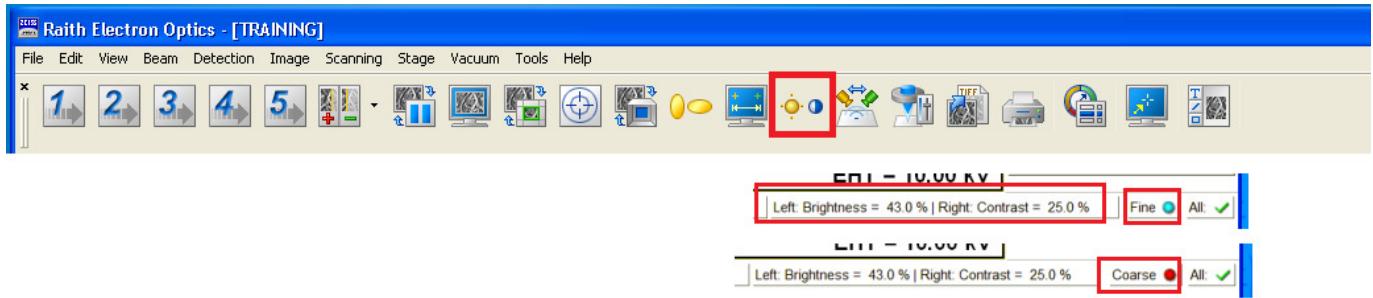
- STEP 4** In addition, the column should be under internal control (IMG icon). If it is not, click on the remote control icon, the icon will then change to the IMG icon.

- STEP 5** You now need to select a low magnification, as this makes it easier to obtain the first SEM image. Go to the Data Zone and double click on Mag. Enter a low magnification, for example 50. You should be now able to obtain a rough image of the sample holder. For better focusing follow the instructions on the next pages.

- STEP 6** Click with the left mouse button on the Detector icon in the column desktop, which changes between INLENS detector and SE2 detector. Ensure, that the INLENS detector is used. Check in the data zone that the required detector is selected. Use the INLENS detector while you are still getting familiar with the system, as it provides a higher signal. The INLENS detector can be used for voltages up to 20keV.



- STEP 7** The next step is to adjust brightness and contrast. Click the icon for Brightness and Contrast. The left and right mouse button will now be assigned for controlling brightness and contrast respectively by horizontal mouse movements. This assignment is shown on the bottom line. First, press the left mouse button and move it while pressing it down to adjust the brightness; then use the right mouse button and the same movement to adjust the contrast. For getting first images a setting of Contrast=Brightness=50% will be sufficient.



The left mouse button is assigned to brightness control and the right mouse button is assigned to contrast control.

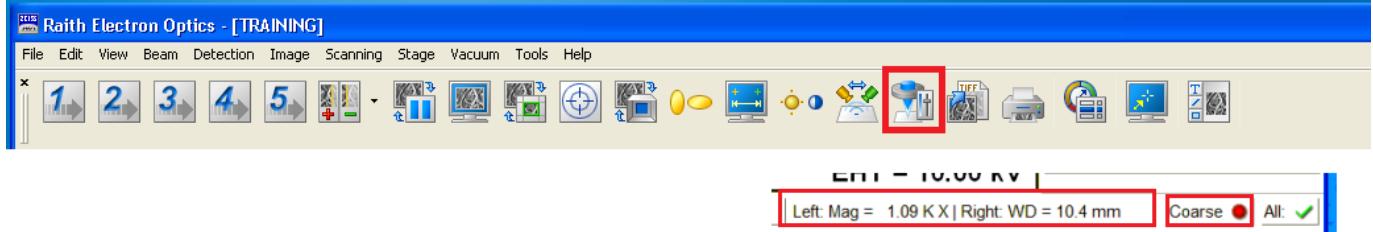
The mouse movement can be toggled between Fine and Coarse by clicking in this field once.

HINT

Click on the Brightness and Contrast icon using the right mouse button in order to start an automatic Brightness and Contrast optimization. Afterwards click the icon again with the right mouse button to switch off the automatic optimization.

STEP 8

Now that the Brightness and Contrast have been optimized, we can now start to focus onto a surface using a selected magnification of 50x. Click on the Mag/WD icon using the left mouse button to assign the left and right mouse button to magnification and focus control during horizontal mouse movements. Now you can optimize the focus by pressing the right mouse button and moving the mouse from left to right or vice versa.



The left mouse button is now assigned to Magnification control and the right mouse button is assigned to Magnification control.

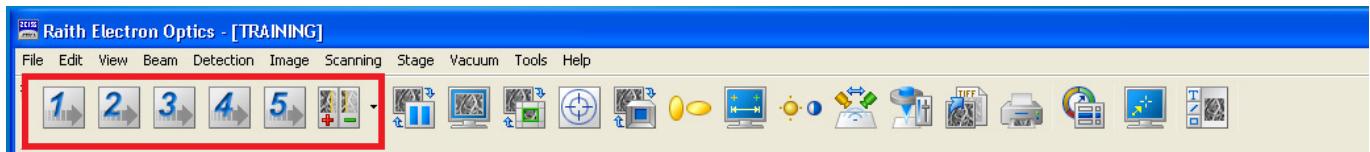
Coarse control.
The mouse movement can be toggled between Fine and Coarse control.

HINT

Please note that the focus is related to the working distance.

STEP 9

As the sample is now in focus, a higher quality image (lower noise) can be obtained by changing the scan speed to a higher number, as this is reducing the scan speed. Change the scan speed to slower scan speeds in order to reduce the noise by clicking the left numbered icons or freeze an image by clicking the icon with the double bar.



The scan speed can be changed by these icons. The higher the number, the slower the scan speed, the higher the image quality (lower noise).

Clicking on these icons with the right mouse button, will switch imaging to continuous averaging. For getting started, right mouse click on icon “2”.

TASK 5: Finding your sample

STEP 1 You can use the joystick to drive the stage to the desired position.

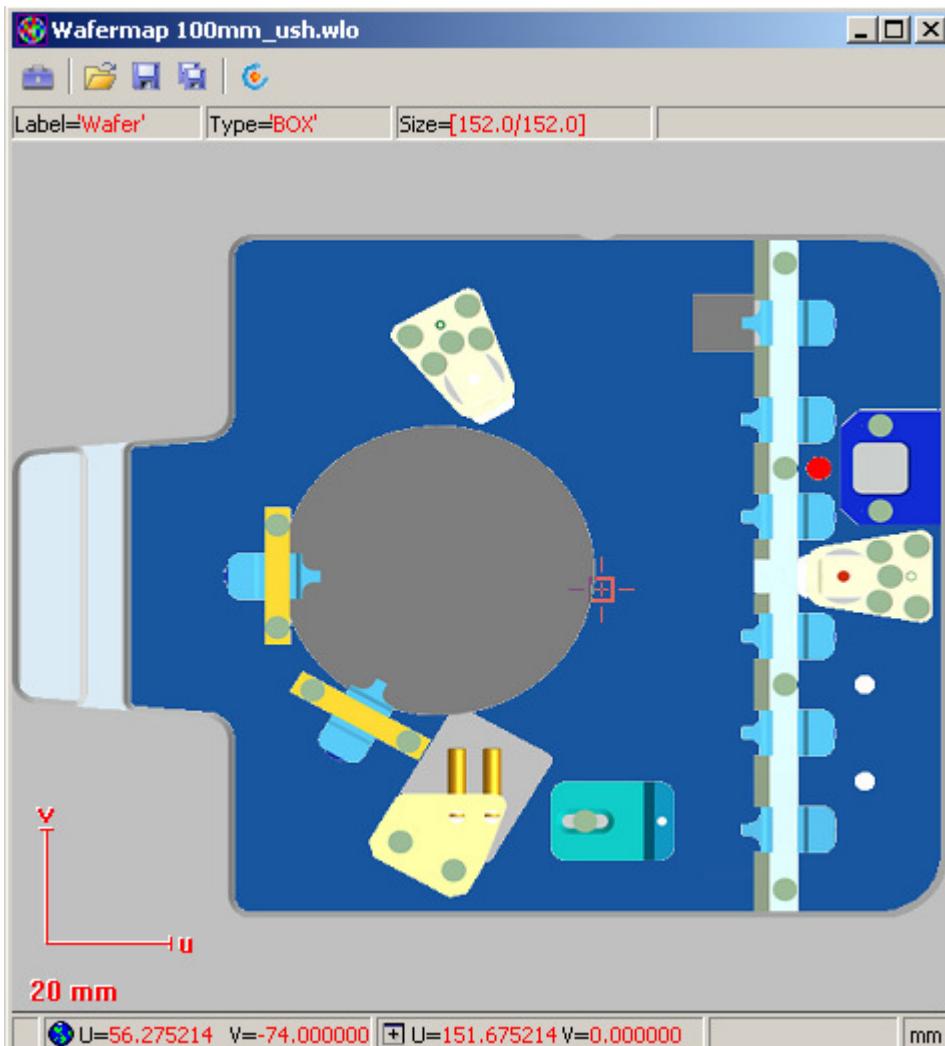
Switch on the X and Y buttons in order to receive the corresponding LEDs lit.



The LEDs on the joystick indicate the corresponding axes, which are under joystick control.

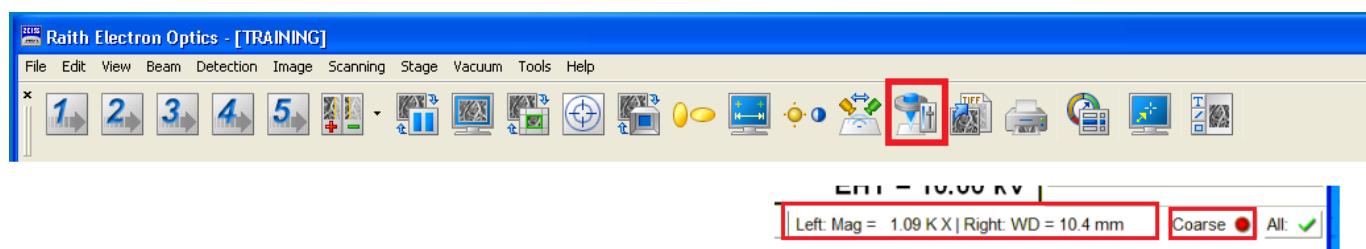
Hint When in CCD-Mode the Beam is internally blanked by the SEM. Move close to your sample but do not move over your sample, otherwise you would start the exposure when you switch back to the SEM image.

It might also be useful to use the Raith wafermap to navigate to your sample instead of the joystick. To do this, open the corresponding wafermap for the sample holder that you have loaded by going to the File menu, Open Wafermap. You can move to a position on the holder by Ctrl-right mouse click on the wafermap.



STEP 2

We can now start to focus on the sample holder using our selected magnification of 50x. Click on the Mag/WD icon using the left mouse button to assign the left and right mouse button to magnification and focus. Now you can optimize the focus by pressing the right mouse button and moving the mouse.



The mouse movement can be toggled between Fine and Coarse control.

HINT

The joystick axes may be aligned differently than from the view of the CCD camera. Therefore the stage movement on the CCD camera may look different than expected.

HINT

Since the CCD camera is viewing the sample at a slight angle, the image will vary in appearance depending on the working distance (pole piece to sample distance). Some practice may be required at first to move close to the sample.

STEP 3

Now that you have optimized the focus, you need to locate the sample at low magnification. Click on the Raster icon to switch back to the SEM image. Move the lower left corner of your sample into the center of the field of view.

HINT

You can turn on a crosshair, indicating the center of your screen, by clicking on the monitor icon with the centered cross.



STEP 4

Press the right mouse button on “2” to switch to continuous averaging with scan speed 4. Scan speeds and averaging modes are available using the other number icons.



HINT The actual stage position can be viewed at all times on the lithography desktop, otherwise open the Coordinates window. The current positions are automatically updated.

Coordinates	
X:	6.286329 mm
Y:	-1.657138 mm
Z:	26.000 mm
U:	-6.200838 mm
V:	-7.406401 mm
W:	9.843 mm



Raith Tutorial-2: Ebeam Optimization

AIM

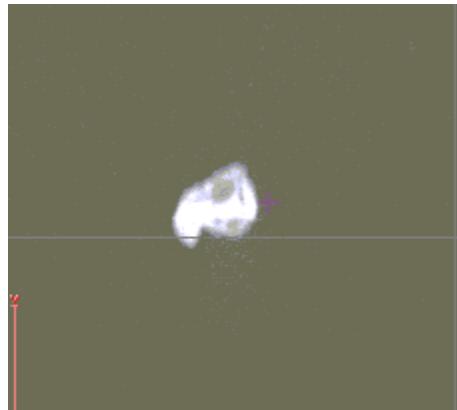
This Tutorial explains step by step how to optimize the column setting in order to get a good exposure by selecting the correct parameters.

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TASK 1: Focusing on the sample

STEP 1 It is assumed that you have loaded a 1 square cm sample into the system as described in the first tutorial. Select a small particle of less than 1 μm on your sample.

STEP 2 Move the particle into the center of the field by using the joystick.



STEP 3 Zoom onto the particle until you seem to lose focus. Remember that the zoom is assigned to the left mouse button after the magnification icon has been selected, as it was described in detail in Tutorial 1.

STEP 4 Refocus onto the particle. Remember that the focus is assigned to the right mouse button.

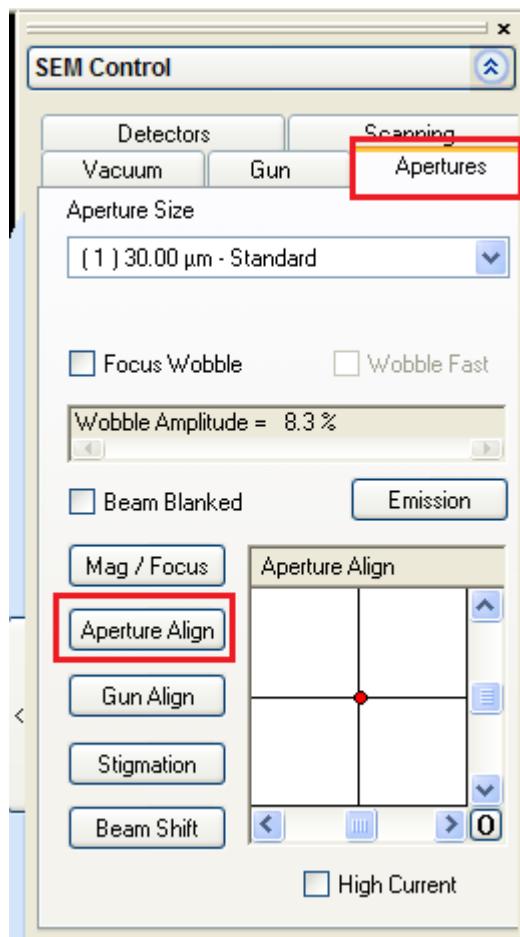
STEP 5 Zoom in further and readjust the focus.

STEP 6 Repeat the zoom and refocus procedure until no further improvement in focus can be achieved.

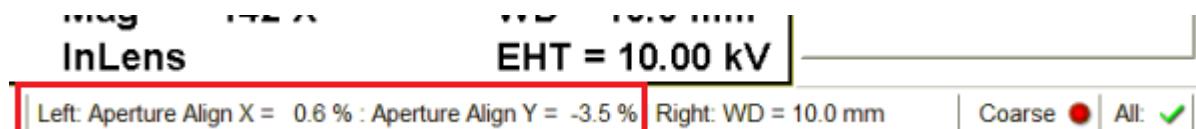


TASK 2: Aperture alignment

STEP 1 In the Column software, on the SEM control panel select the Apertures tab.



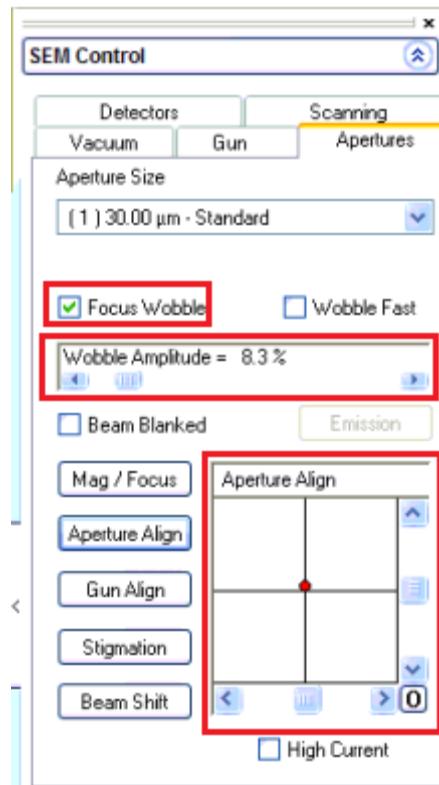
STEP 2 Click on Aperture Align, which assigns the left mouse button to the Aperture alignment in XY by moving the mouse in XY direction. The assignment is displayed in the status bar on the bottom of the screen.



STEP 3 Keep the left mouse button pressed and move the mouse along XY axes. You can observe the changes by viewing the image and a corresponding movement of the red point in the window. In addition you can point the mouse on the red point and drag it around while keeping the left mouse button pressed. A third alternative for adjustment is using the scrollbars.

STEP 4 The next step is to switch on the Focus Wobble in the Apertures tab of the SEM Control by marking the corresponding field and select an useful

amplitude for the current magnification. This will cause a periodic change of focus and during this cycle the image will move periodically in some direction.



Select a suitable Wobble Amplitude by using the slider bar

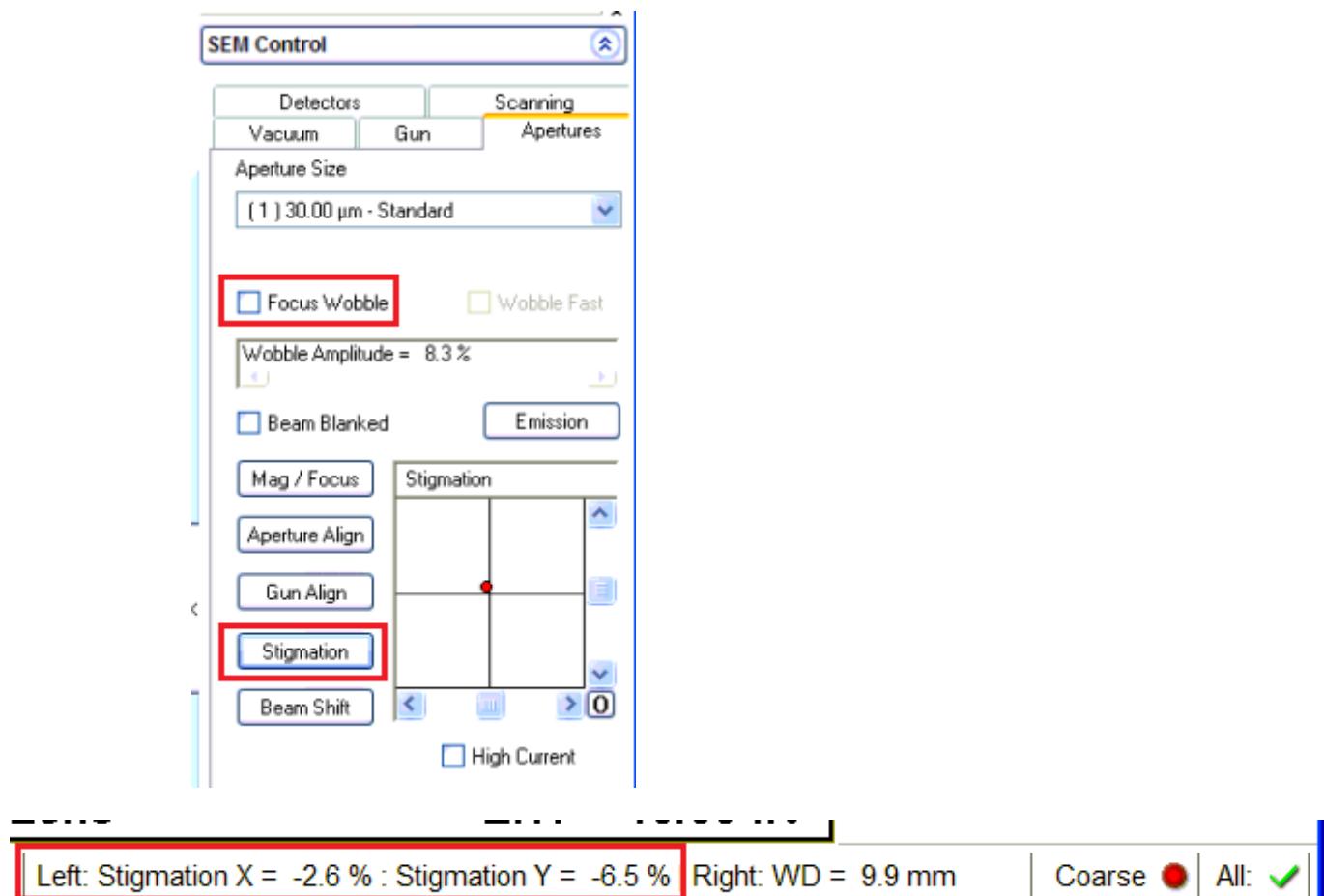
Observe the movement of the red dot in the Aperture Align window

- STEP 5** The key to aperture alignment is to minimize the image shift during the wobble sequence. To achieve this, move the mouse in the X and Y direction while keeping the left mouse button pressed and optimize for lowest image movement.
- STEP 6** You might be able to improve the aperture alignment even further by repeating the same procedure at higher magnification and reduced wobble amplitude.

HINT If the dust particle becomes too large at high magnification, move to a smaller dust particle and continue the optimization. In order to change the magnification, click on the button Mag/Foc. Do not forget to switch back to Aperture Align once finished.

TASK 3: Astigmatism correction

- STEP 1** Click on Stigmation, which assigns the left mouse button to the stigmation alignment. The adjustments are carried out in the same manner as the aperture alignments.



- STEP 2** You may wish to switch on the Focus Wobble in the Apertures tab of the SEM Control by clicking on the corresponding field and select an useful amplitude for the current magnification, as was done in the above Task – Aperture alignment. During the wobble sequence the particle will be stretched first in one direction and then in the perpendicular direction.

- STEP 3** Optimize for lowest shape changing of the particle.

TASK 4: Further Ebeam optimization

For the final optimization of the E-beam, you need to change between Aperture Alignment and Astigmatism Correction several times in order to optimize the settings for high image quality at higher magnifications. The final result should be a high quality image of the particle at a magnification of 300,000x or higher and the creation of a contamination dot for final optimization, as described in the next task.

HINT Remember that during the aperture alignment we are correcting any image movement, while during the stigmation optimization we are correcting any shape changes.

- STEP 1** Perform the Aperture alignment again at higher magnification and reduced wobble amplitude. In order to change the magnification, click on the button Mag/Focus and use the mouse.
- STEP 2** Perform the Astigmatism correction again at a higher magnification.
- STEP 3** Continue the alignment optimization without the use of the focus wobble by alternating Aperture Alignment (left mouse button) and the manual Focus (right mouse button). The aim is an aperture alignment which avoids image shift during defocusing. This method allows a more precise adjustment than the automatic wobble and is recommended for the final optimization steps.
- STEP 4** Repeat the same procedure between the optimization of Aperture alignment and Astigmatism correction until no further improvement can be achieved.

TASK 5: Creating a contamination dot

After completing the E-beam optimization, for the final optimization of the aperture alignment and astigmatism correction, you will usually burn a contamination dot.

- STEP 1** Check the focus quality at one particle at a high magnification of at least 100,000x or higher. Once satisfied with the image quality, move the stage a small amount away from the particle and to a space on your sample that has not already been rastered by the beam. Sometimes it is a good idea to blank the beam and then move slightly with the joystick.
- STEP 2** Click on the Spot icon in the column toolbar. Clicking with the left mouse button will burn a dot for a duration of 3 seconds. The software will automatically switch to reduced scan area. Clicking with the right mouse button will burn a dot until you click again with the right mouse button. If you were not able to burn a visible contamination dot, click with the right mouse button and wait a longer period of time, 30 seconds to 1 minute.



- STEP 3** Focus again on the contamination dot, move the stage and burn another contamination dot. The new dot should be smaller since the focus has been improved.

HINT If the dot is not round, apply the aperture alignment and then the astigmatism correction again, now using this dot. Using such alternating routines, it is possible to achieve an ideally round dot, which grows within a few seconds of exposure time and shows perfect alignment. The optimization on this dot provides now the optimized conditions for a real exposure nearby.

TASK 6: Check the level of your sample

HINT Depending on the size of your sample, it is likely that your sample surface is tilted to the beam. This can be checked by the following tasks. The user should be aware of this.

- STEP 1** Switch to a lower magnification and move the stage for a longer distance, i.e. 1mm. Ensure that you notice the direction of movement in order to relocate the previous contamination dots.
- STEP 2** Burn another dot and view the result. This dot now is likely to be larger than the previous one. But this time, the focus adjustment should be sufficient for the optimization. It should not be necessary to perform the aperture alignment and astigmatism correction again.
- STEP 3** Perform some experiments to establish the stage travel distance, at which you need to refocus the sample surface.
- STEP 4** Move the stage to the opposite corner of the sample, where also some of the deposited metal particles are located. After moving over such a long distance, it is likely, that it will not be possible to burn a dot. Use the metal particles to focus on the sample surface.

HINT To improve the levelling of small samples, it is recommended to use two opposite clamps. In addition, it is possible to solve the levelling problems by an auto focusing routine or by piezo levelling for large samples. These routines will be explained in later tutorials.



Raith Tutorial-3: Stage Adjustment

AIM

This tutorial describes stage adjustment, which allows navigation with a blanked beam on the sample in order to find a new exposure area without pre-exposing or to find an already exposed and processed area for inspection or multi-layer exposure. The two coordinate systems (XY for the stage and UV for the sample) will be explained in detail, thus permitting the determination of the correct UV sample coordinates independent of how the sample has been mounted on the stage.

In this tutorial we will explain in Task 1 and 2 how to expose a pattern on a bare sample. In Task 3 we will explain the stage adjustment on a patterned sample.

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HINT

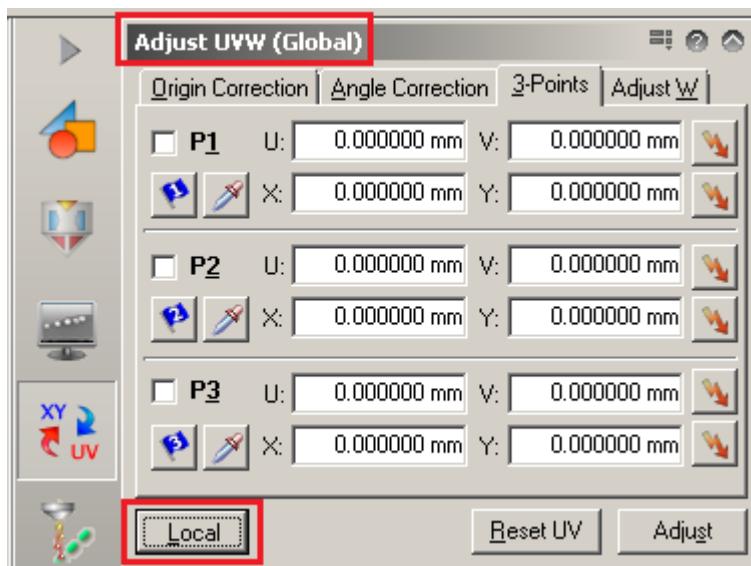
The primary coordinates are the stage coordinates X and Y, which describe the stage position relative to the electron beam. They do not give any information regarding the position on the sample, because it is not known how the sample is mounted on the stage. The “trick” is therefore, to have a second coordinate system U, V, which is sample related.

HINT

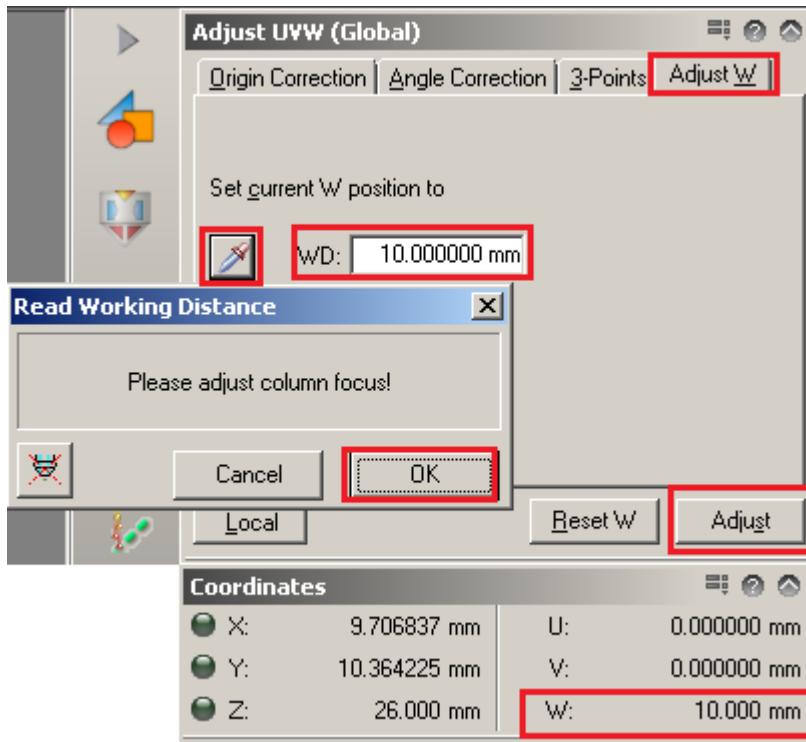
The aim of stage adjustment is now to find the relationship between XY and UV with respect to shift, scaling and rotation in order to perform a permanent coordinate transformation between both systems.

TASK 1: Angle correction

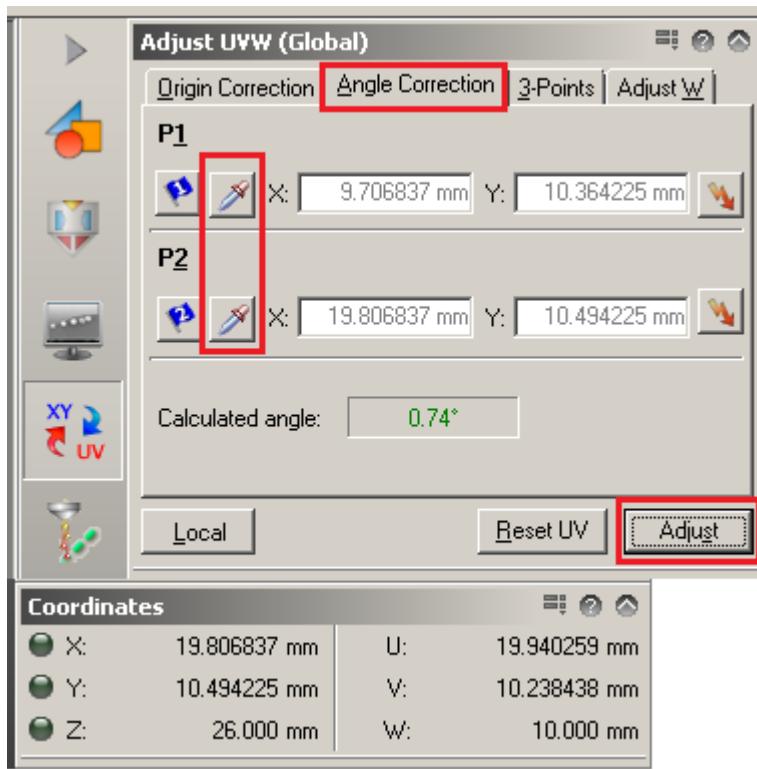
- STEP 1** On the column desktop, image the sample at medium magnification, approximately 300 – 500x. Ensure that the crosshair is switched on (View->Crosshairs) in the column desktop, and move the stage so that the crosshair is situated on the lower left corner of the sample.
- STEP 2** On the lithography desktop, open the window Adjust UVW. Ensure that it is on Global; if it is on LOCAL, click on the button in the lower left corner of the window once to change it to GLOBAL.



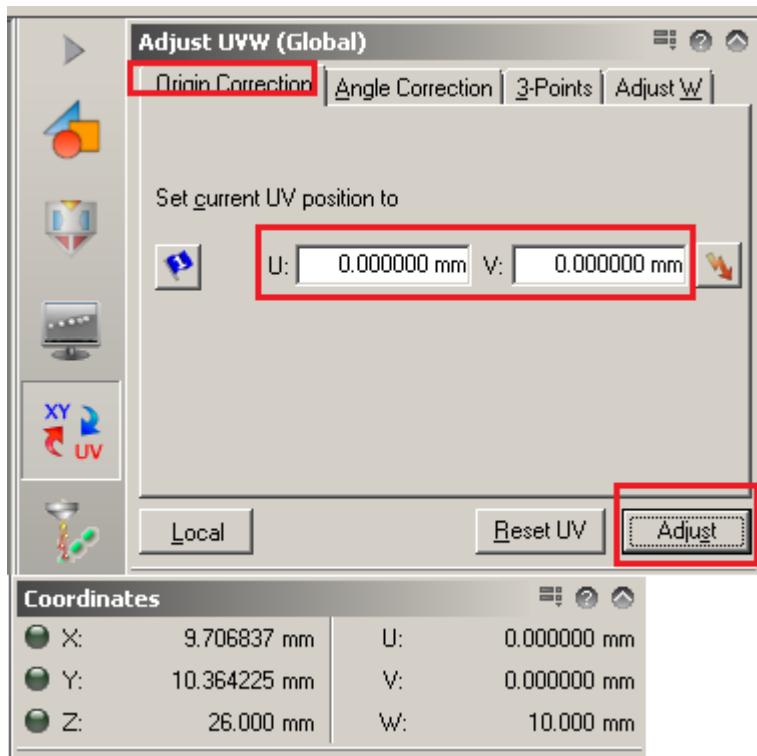
- STEP 3** Identify the lower edge of the sample and follow this edge to the lower left corner of your sample. Move slightly onto the sample and find some dust particles to determine that your sample is still in focus.
- STEP 4** Click on the page Adjust W in the Adjust UVW (Global) window. Press the “eye-dropper” icon. The software will ask you to focus, then press “OK” to “read” the working distance from the column. Then click on Adjust button. The W of the coordinates window will now display the column working distance.



- STEP 5** You can now use the Stage Control window to drive the stage to the desired working distance for your patterning.
- STEP 6** Identify the lower edge of the sample and follow this edge to the lower left corner. In the coordinate window the actual XY coordinates are displayed. Click on “eye-dropper” icon to “read” the XY coordinates of the first position of Adjust UVW and the coordinates will be displayed in the window.
- STEP 7** Once the coordinates for P1 have been read, switch back to low magnification and move the stage a few millimeters along the sample edge to the lower right corner. Move the stage so that the cross hair is situated on the lower right corner. Click on the “eye-dropper” icon to “read” the XY coordinates of the second position of Adjust UVW and the second set of coordinates will be displayed in the window.

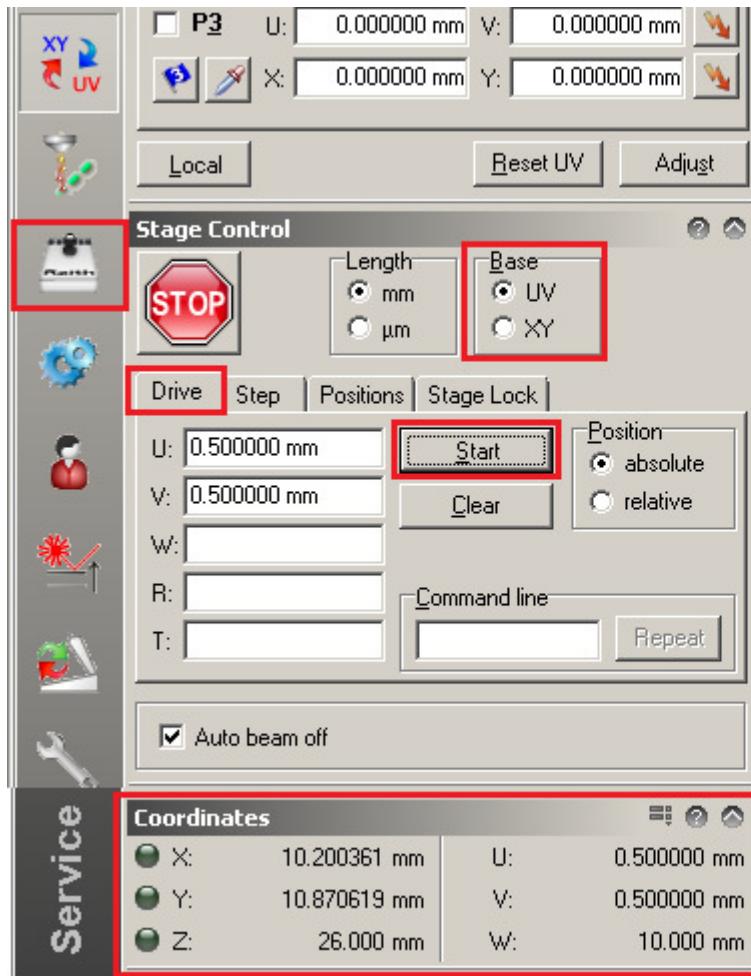


- STEP 8** Click on Adjust to calculate the angle, in this case the angle is 0.74 degree. The angle will change in color from red to green.
- STEP 9** Click on the lightning icon next to the first Read coordinates to move back to the lower left corner.
- STEP 10** Click on the Origin Correction tab and enter (0,0) for both the UV values, then click on Adjust. The lower left corner is now defined as the origin of this UV coordinate. It is now possible to move the stage to any point on the sample using UV coordinates.



TASK 2: Digital addressing

STEP 1 In Task 1 we have established a coordinate system in UVW, which we can now use to address certain points on the sample. This will be explained in this task. Click on the Stage Control window and then on the Destination tab.



Click "Drive" in the Stage Control window

Select Base UV and Position "absolute"

Click on Start to move to the coordinates entered.

The Coordinates window displays the XYZ and UVW coordinates always

HINT The Stage Control window is accessible from either the "Adjustments" icon or the "Stage Control" icon

STEP 2 Click on Base "UV" and Position "absolute". Now you can address the stage to any position in UV. W describes the working distance, which is directly related to the stage height Z. If you do not want to change the stage height (working distance) leave the corresponding line blank (this was set in the previous Task, Step 4. After clicking Start, the stage will move to the sample position entered. In the Coordinates window, you

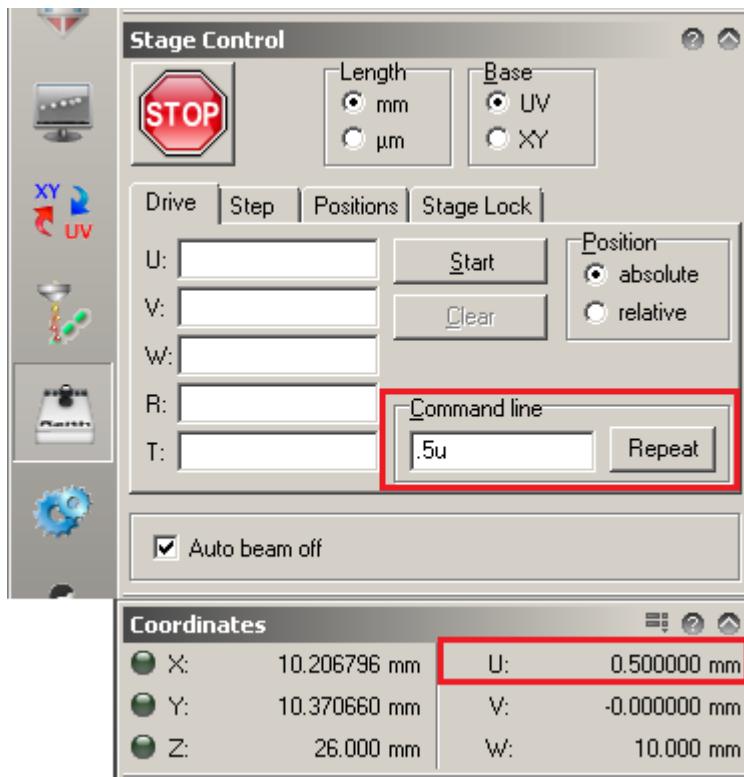
will see the addressed sample position and the corresponding position in XYZ.

HINT

Remember to pay attention to the Position (absolute or relative) and the Base (UVW or XYZ) that is selected.

STEP 3

In the Command line dialogue box, it is possible to address just one axis, either absolute or relative, by entering the required position or distance followed by the letter of the axis you wish to drive in.

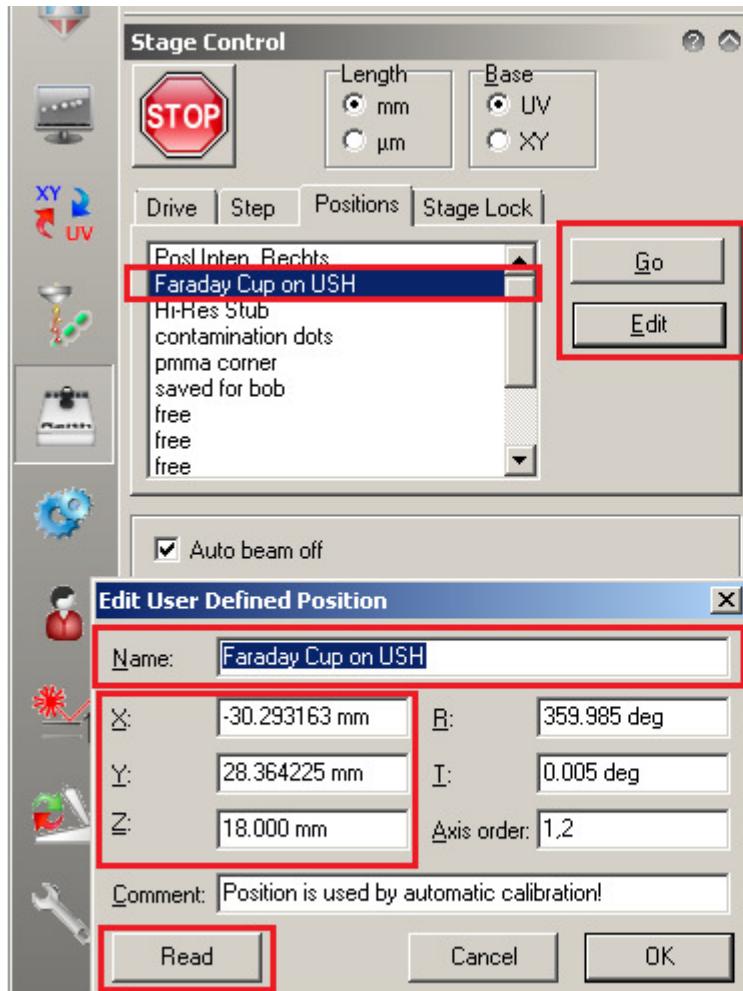


HINT

Type in small letters (u, v, w, x, y, or z) to drive the stage in “absolute” coordinates and capital letters (U, V, W, X, Y, or Z) to drive the stage in “relative” coordinates.

STEP 4

Now click on the “Positions” tab. In this window, it is possible to drive the stage to a stored position, the stage coordinates of which have been entered previously. In this example, the stored position is the Faraday cup, its address is only in XY as its position is independent of Z. To edit a position, you can either enter the desired position or you can read the current position, if the stage is already at the selected point.



Select a Position and either "Go" to drive the stage or "Edit" to modify the coordinates.

Name of the user-defined position

Position coordinates and order the axis will drive
(X=1, Y=2, Z=3)

Once the stage is at the specified position, you can use the read button to store the coordinates.

HINT

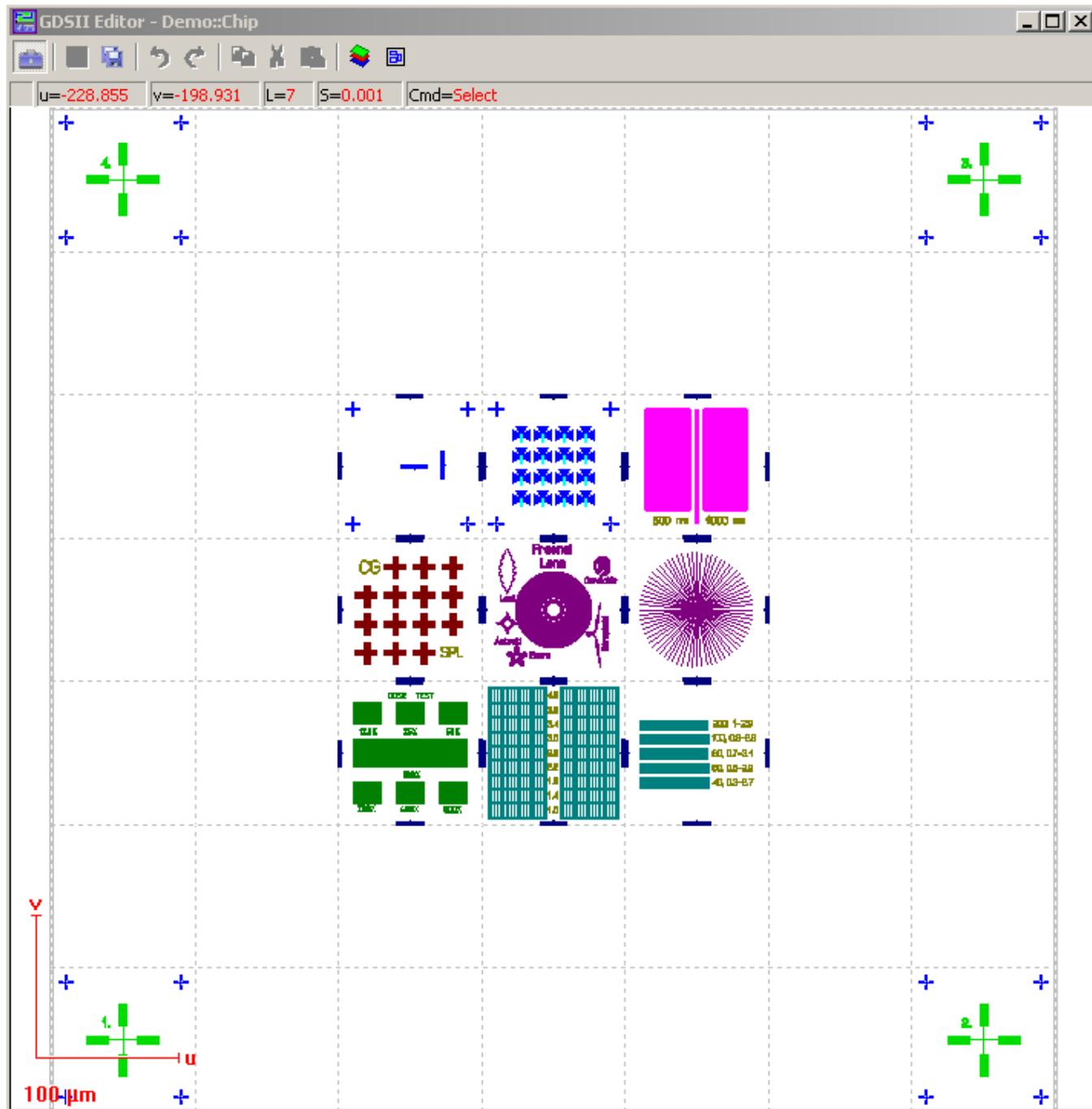
The establishment of a coordinate system (U,V) via the Angle and Origin Correction is primarily used for patterning on a blank sample, which has to be exposed. If the sample will be inspected after external processing or a second write or "overlay" is necessary, it is possible to relocate the previously patterned areas again after repeating the same alignment procedures.

HINT

If you are patterning on a blank sample, move on to the next Tutorial – WriteField Alignment. If you are patterning on a previously written sample, i.e. doing an overlay exposure, proceed to Task 3.

TASK 3: Adjusting to a patterned sample

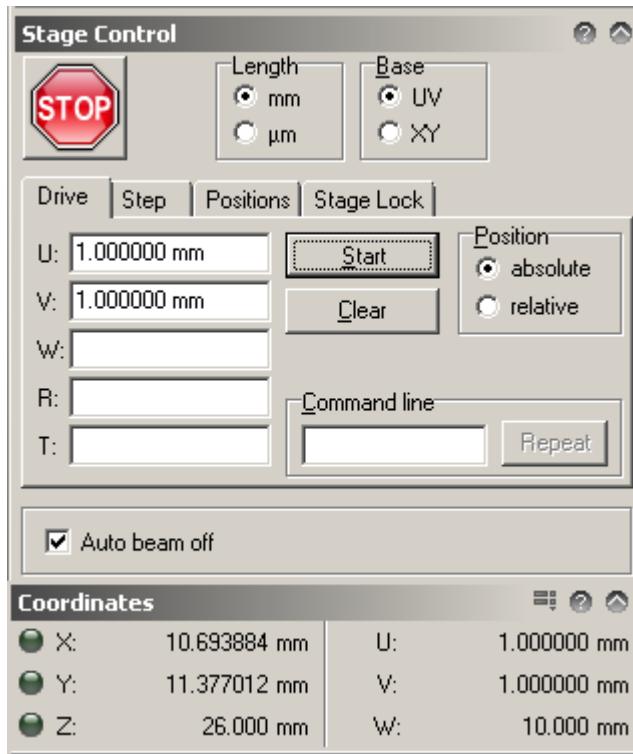
STEP 1 Once the sample has been developed and reloaded, repeat Task 1 as previously done to establish the “Global” UV-coordinate system of the sample. It is important to use the same “origin” point as previously used to make the navigation on the sample to find your pattern easier.



STEP 2

The pattern that will be written during these Tutorials is shown above, the standard Raith Demo pattern. The above pattern has been already written and we now wish to either A) navigate and inspect the pattern and/or B) perform an overlay exposure. In either case, we need to establish a new “Local” coordinate system.

Using the Stage Control window, drive the stage to the (U,V) coordinates where the pattern was written, the (U,V) coordinates from the Positionlist. In the image shown here, these are (1,1).



STEP 3

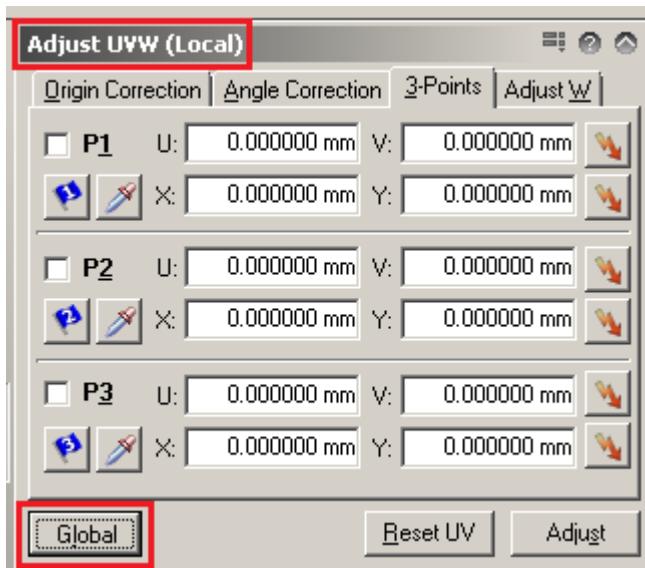
Unblank the beam and image with the Column, you should be close to centered over the large cross marked “1” in the lower left corner of the pattern.

HINT

Use caution when unblanking the beam and keep in mind the magnification that you are using so as not to expose your resist.

STEP 4

Open the Adjust UVW window and select the “3-points” tab. Set the system to a “Local” coordinate by pressing the button in the lower left corner. The word “Local” will be displayed “Adjust UVW (Local)” as shown in the following image.

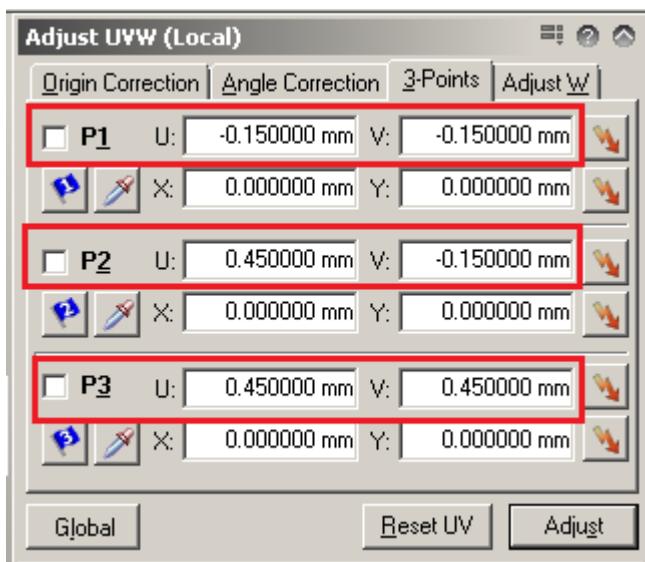


STEP 4 You will be using the GDSII coordinates of 3 of the Global Marks to establish a 3-point “Local” coordinate system. You will need to record the center coordinates of 3 crosses (for this Task, we will be using 1, 2, and 3).

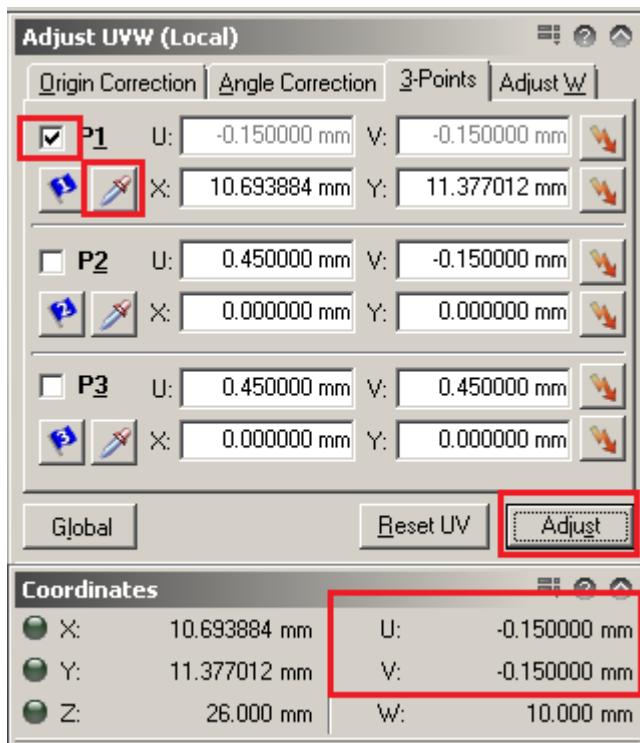
STEP 5 From the GDSII design, here are the coordinates of each cross:
cross 1 (-150,-150), cross 2 (450,-150), cross 3 (450,450) μm .

HINT Pay attention to the coordinates! The GDSII design is in units of “microns” while the Adjust UVW window is in “millimeters”.

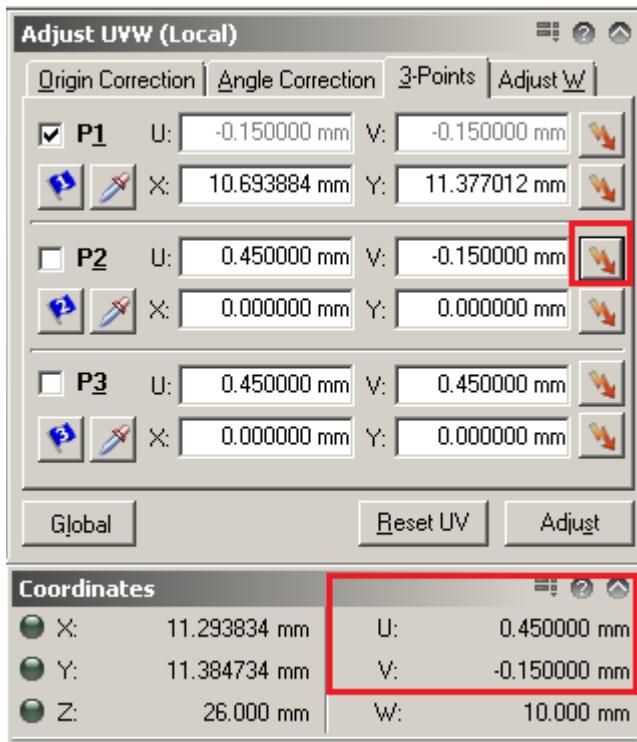
STEP 6 Type these values into the corresponding P1, P2, and P3 values for UV.



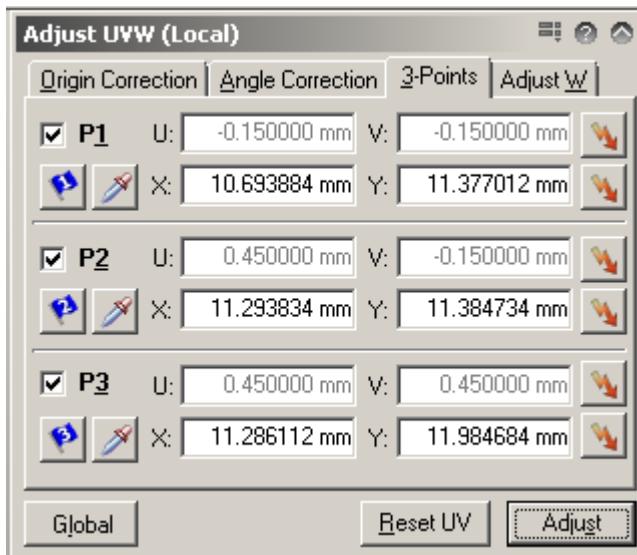
- STEP 7** Now image the first cross with the Column and center the crosshairs on the cross. Use a magnification of approximately 4k – 10k.
- STEP 8** In the Adjust UVW window, read the current XY coordinates of the stage by clicking on the “eye-dropper” icon for P1. Next, place a “check” in the box next to “P1”, and then press “Adjust”. The first point of the Local coordinate system has now been established and you will see these coordinates reflected in the Coordinates window.



- STEP 9** Now you need to drive to the second mark. Since the “Adjust” button has already been pressed, the stage has a coordinate reference of (-150,-150). Press the “lightning bolt” icon next to the UV coordinates of P2, and the stage will drive to that coordinate, (450,-150).



STEP 10 Repeat Step 8 for P2. Then repeat Steps 9 and 8 for P3. The Adjust UVW/3-Points window should look like the following.





Raith Tutorial-4: Writefield Alignment

AIM

This tutorial explains the alignment procedure for an exact writing field. In the previous tutorials, the image scan has been under the control of the column software. In order to perform lithography, the beam has to be controlled via the lithography software. For this to be done accurately, a writefield alignment has to be performed. The procedure described in this tutorial via Align Writefield is required for stitching and for all exposures on a bare sample. The alignment of the field size to previously written marks for multi-level (overlay) lithography will be explained later in this tutorial.

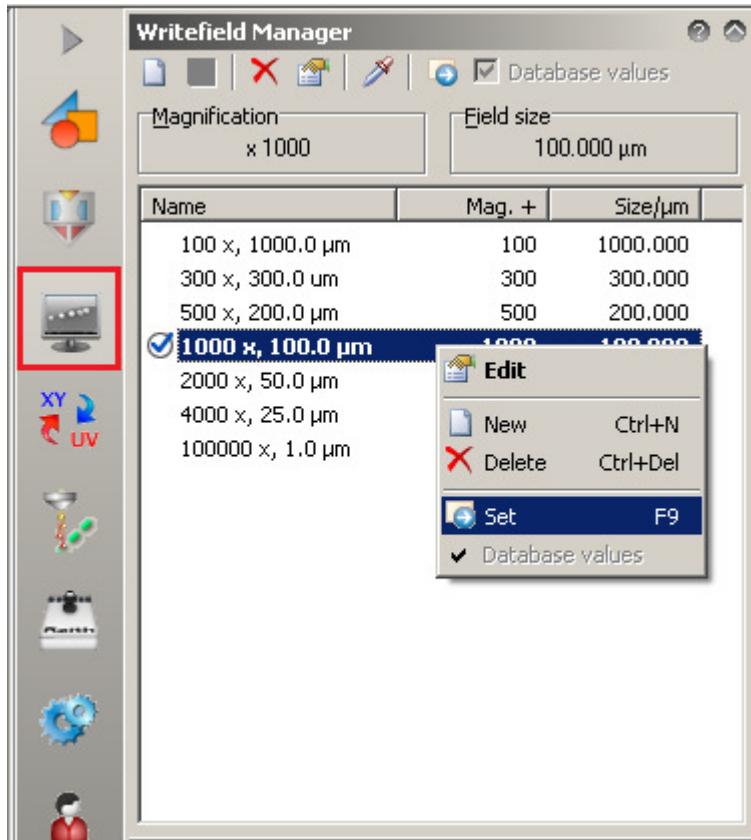
TASK 1:	Aligning a WriteField	41
TASK 2:	Multi-level (overlay) alignment	48

HINT

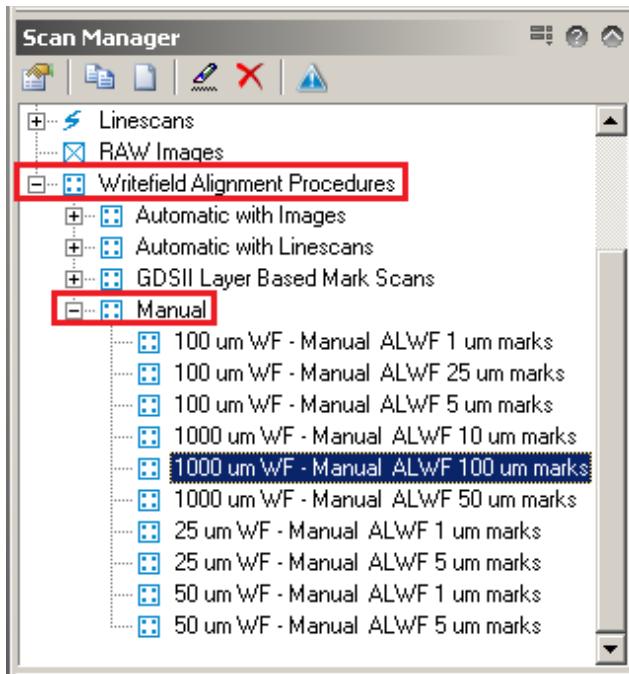
The Align Write field is a very important task, as it aligns the write field to the sample coordinates UV. In Tutorial 3, we performed a point navigation in UV, but the image via the column software was still parallel to XY at a certain point and non-parallel to UV. For pattern stitching, it is essential that the write field is exactly parallel to UV and this can be achieved with the align writefield procedures.

TASK 1: Aligning a write field

- STEP 1** In the Raith software, go to the Microscope Control/Writefield Manager window and choose the desired WF setting for your patterning. In this case, set the system to a 100 um WF.



- STEP 2** Move the stage back to the lower left corner of the sample and locate a small particle. Check the focus.
- STEP 3** Go to the Scan Manager Window/Writefield Alignment Procedures and expand to the "Manual" procedures.



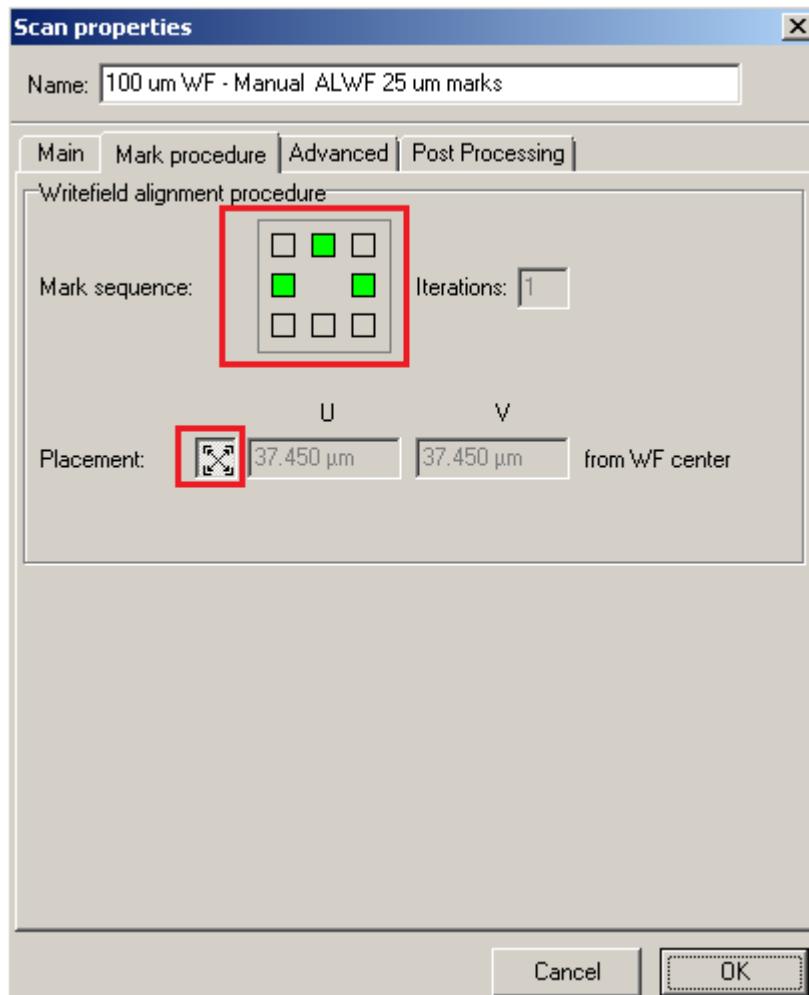
STEP 4 Go to the Scan Manager Window/Writefield Alignment Procedures and find the procedure you wish to run. Right-click on that procedure and select “Properties”. A corresponding window will open.

The image shows two windows side-by-side. On the left is the 'Scan properties' dialog box, which contains settings for a scan named '100 um WF - Manual ALWF 25 um marks'. The right window is the 'Scan Manager' interface, showing the same list of alignment procedures. In the 'Scan Manager' window, the procedure '1000 um WF - Manual ALWF 100 um marks' is selected and has a context menu open. The 'Properties...' option in this menu is also highlighted with a red box.

STEP 5 On the “Main” tab, define the “Scan size” of the mark and the “No. of points”; in this case, set the “Scan size” to 25 mm and the “No. of points” to 500. Use the calculator button next to “Step size” to satisfy the equation: “Scan size” = “Step size” x “No. of points”

HINT If a non-valid value for mark size or the No. of points is entered, the software will give you a warning message and the “OK” button will be disabled.

STEP 6 On the “Mark procedure” tab, define the number of marks to be used and the location of each.



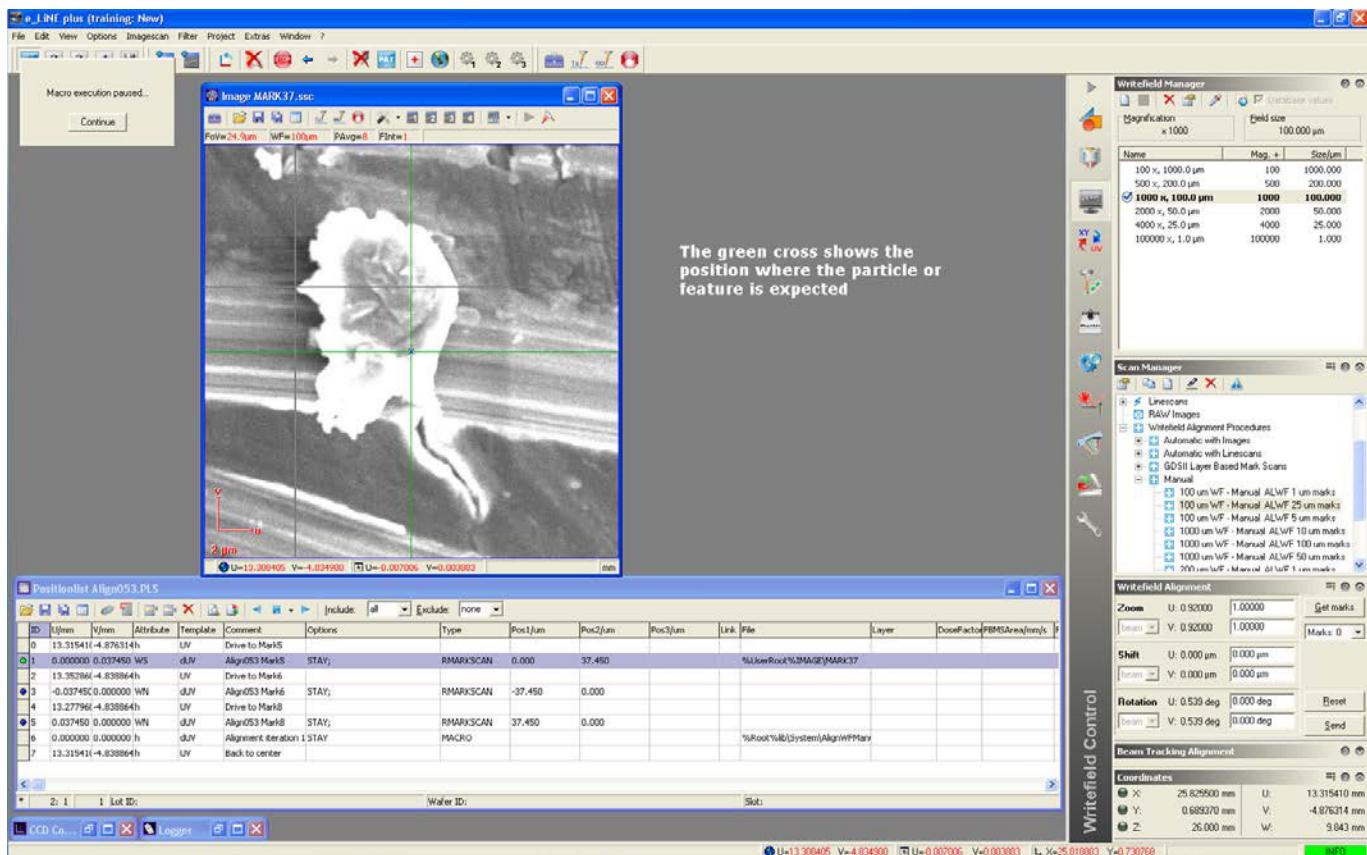
HINT A minimum of 3 mark is needed to perform the align writefield procedure properly

HINT

You can enable the “autoplacement” function by pressing the icon. The software will now place the marks automatically as far as possible into the far corners of the writefield.

STEP 7

Right-click on the procedure and select “Execute” or Drag-n-Drop the procedure into a Positionlist and “Scan”. This will initiate the alignment process. A new Positionlist, “Alignxxx.pls” will be created. Each step as outlined in the Positionlist will be performed. First, the stage will move 37.45 μm in UV to $\square\text{m}$ in $\square\text{m}$ square. The marks will be taken that is 25×25 automatically open, where the particle should be visible.



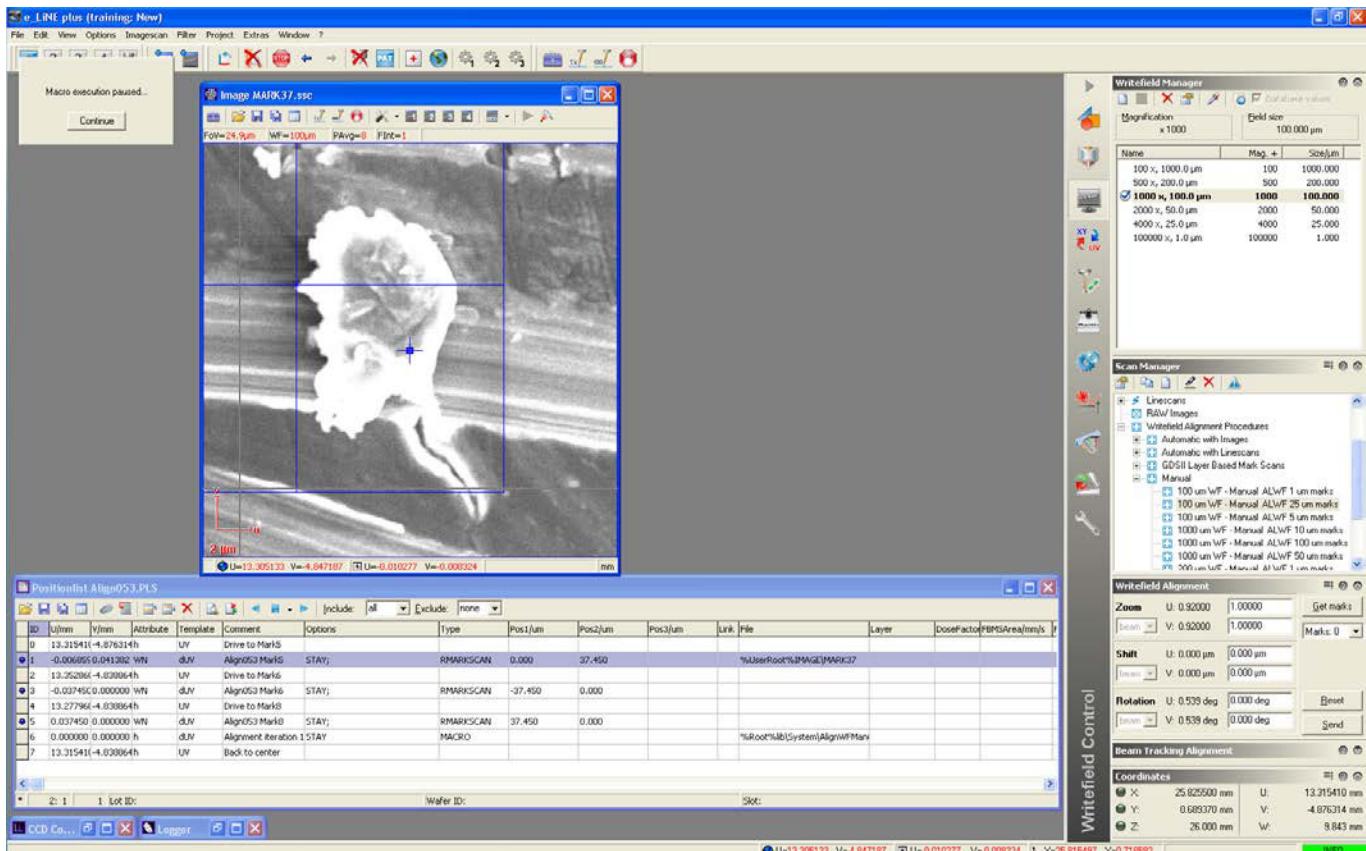
HINT

If the particle is not visible, simply confirm the “Continue” prompt and then select “Cancel” at the end of the procedure. Repeat the task with a larger markscan size, as explained in Step 5.

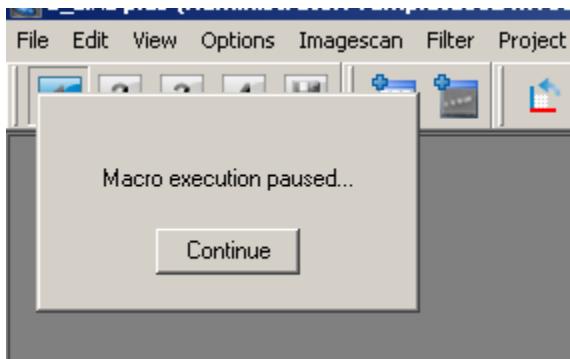
STEP 8

The green cross displayed in the center of the image defines the center location of the imagescan taken, where the particle is expected to be. As this is the first ALWF

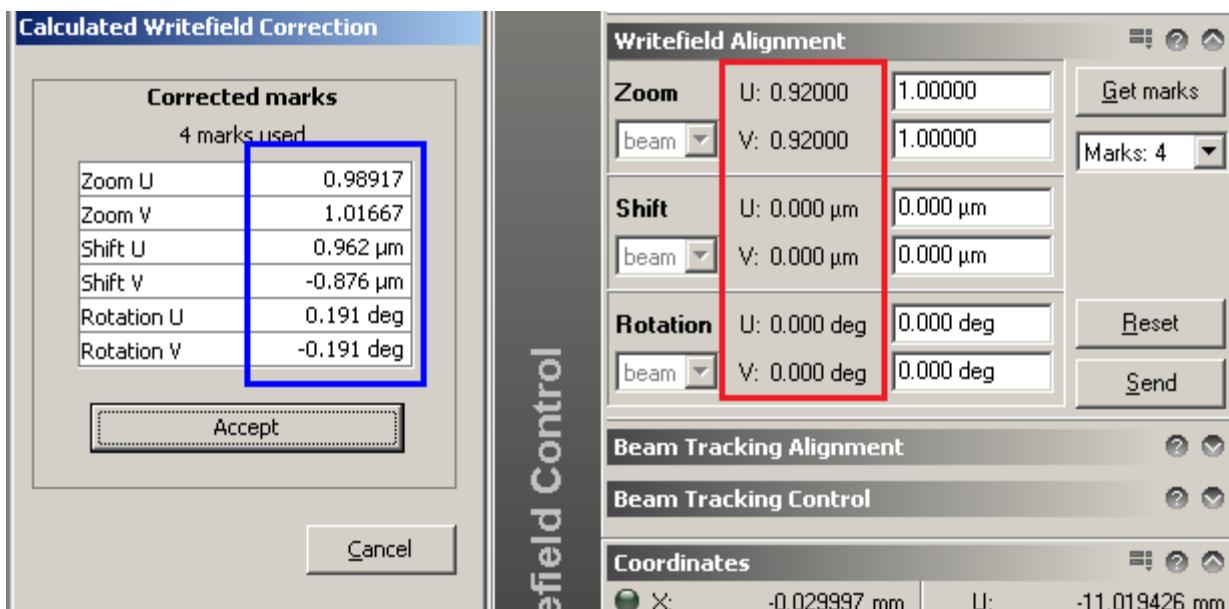
procedure, the particle will probably not be at the center of the imagescan, but the user can now define this position manually. To define the position of the particle, press the Ctrl key and the left mouse button together and hold while moving the mouse cursor to the required position, i.e. over top of the particle. Once you have reached the new position, let go of the Ctrl button and the left mouse button and a blue cross will be displayed at the selected position.



STEP 9 Click on the “Continue” button and the stage will move to the next UV position to perform the same particle alignment. Repeat these steps for each mark position defined on the “Mark Procedure” tab.



STEP 10 At the end of the procedure, a dialogue window will open and the writefield corrections has to be confirmed. Note the values for the Zoom, Shift, and Rotation in UV and confirm them if the values are acceptable.



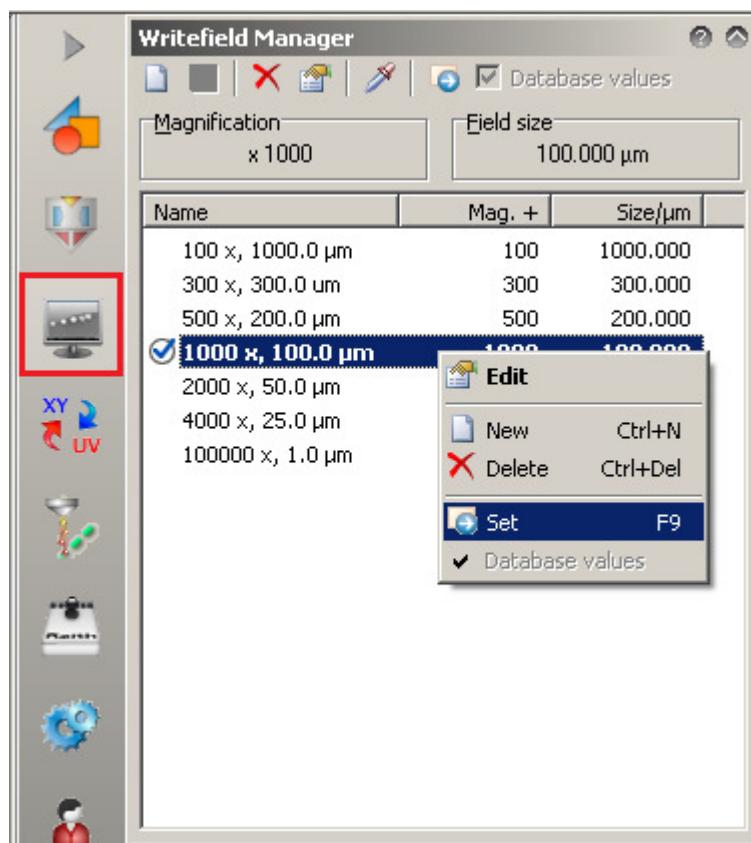
HINT The numbers on the left-side (red) of the Alignment window show the “before” alignment values. As a result of the alignment procedure, new values have been calculated as shown in the “Calculated Writefield Correction” window (blue). By accepting these values, these will be sent to the pattern generator and the left-side values will be updated.

- STEP 11** Go back to the Scan Manager window and repeat the procedure several more times by using a smaller “scan size” for each subsequent iteration. The previous alignment parameters will be used for each subsequent procedure, therefore the particle will be positioned close to the center of the imagescan. The procedure should be iterated until the correction values, shown in the above image in “blue” are as close to 1.0000 or 0.9999 in value for Zoom.
- STEP 12** You are now ready to set up your Exposure.

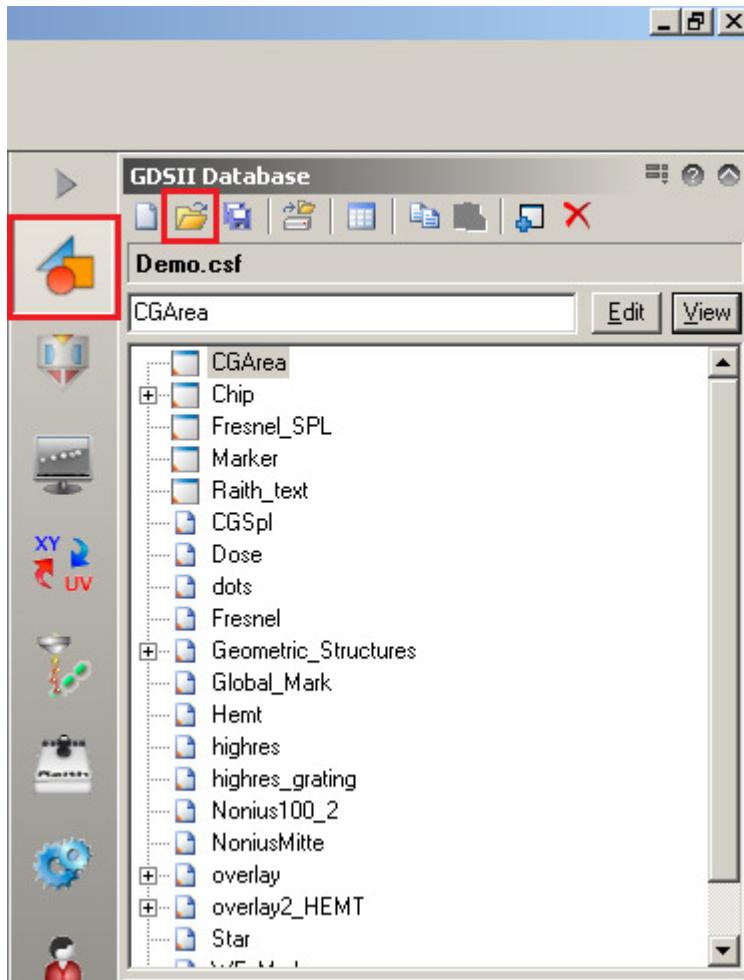
TASK 2: Multi-level (overlay) alignment

The previous Task dealt with alignment of the beam deflection for writing on a bare substrate. In this Task, we will look at the alignment procedures for a sample that has already been patterned, whether by optical or e-beam lithography, and you wish to “align” a second write to this previously written pattern.

- STEP 1** You should have already performed the Steps of Tutorial 3, including Task 3 – “Adjusting to a patterned sample”.
- STEP 2** Obtain optimum focus by burning contamination dots and correcting for astigmatism and aperture alignment.
- STEP 3** In the Raith software, go to the Microscope Control/Writefield Manager window and choose the desired WF setting for your patterning. In this case, set the system to a 100 um WF.



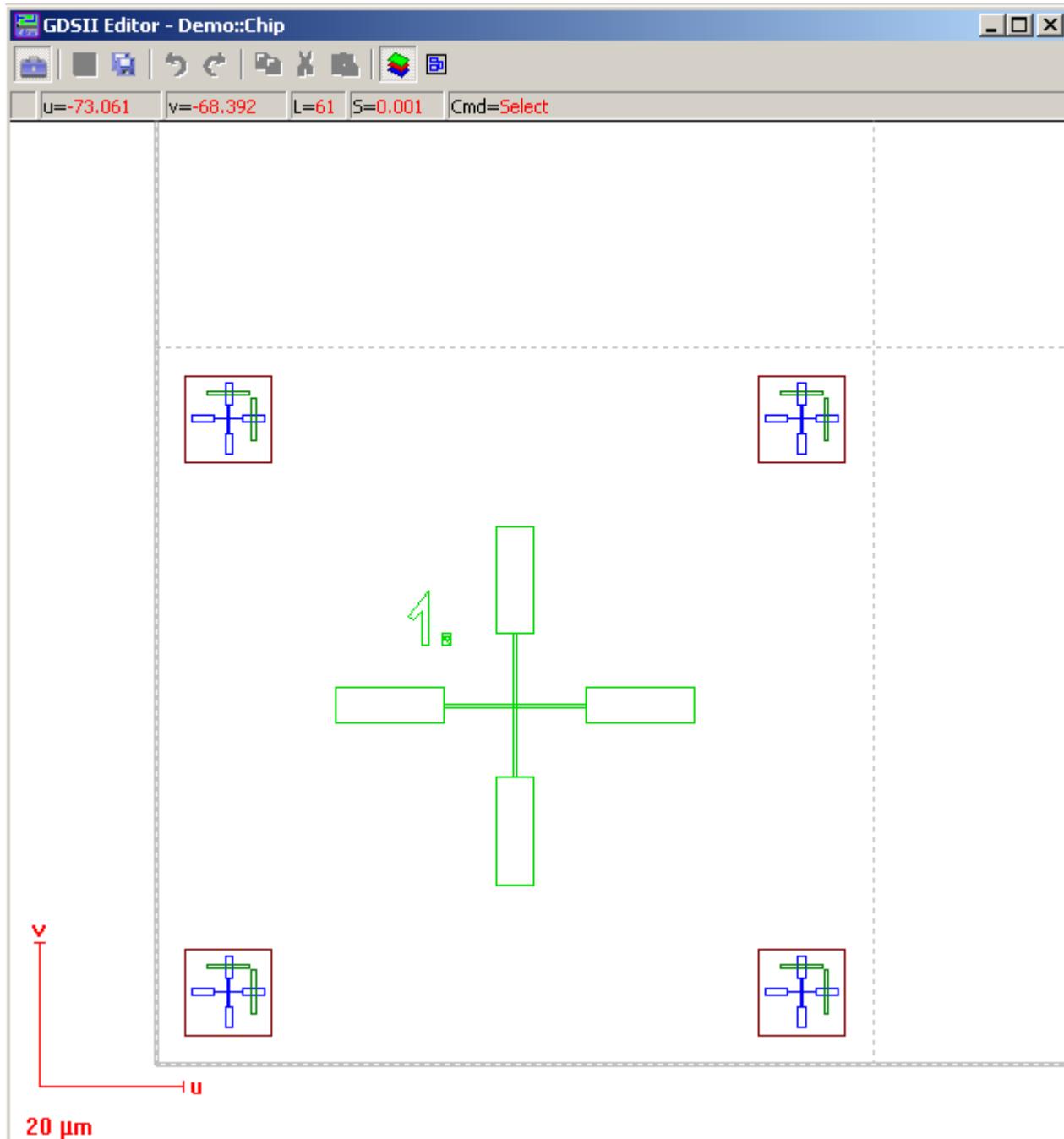
- STEP 4** Go to the Design module/GDSII Database and open the “Demo.csf” pattern.



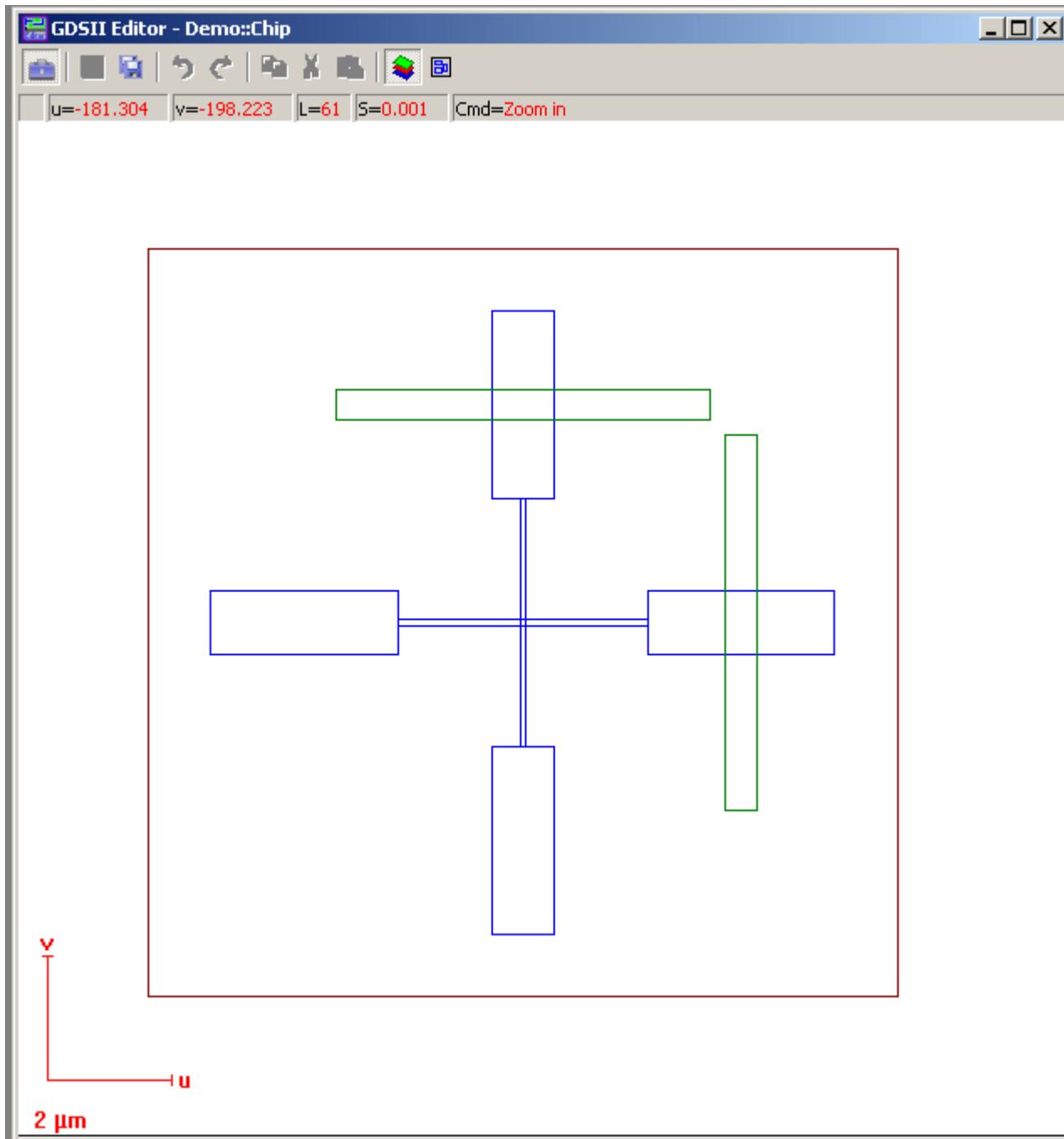
STEP 5 For the Overlay alignment, we will be using Layers 63 and 61 of the GDSII editor, Manual and Automatic markscans. The image below shows one of the Global Marks that was used for the Local 3-point alignment in Tutorial 3 – Task 3. The 4 blue crosses in the corners of the WF were written during the first write and will be used now for alignment of the writefield.

HINT The purpose of the Manual markscans is to obtain a preliminary alignment so that when the Automatic markscans are executed, they will find their targets.

HINT Layer 63 and 61 are reserved in the Raith software for Alignment procedures and have associated macros and scripts that are executed when these layers are called. The users should avoid placing anything else in these layers.

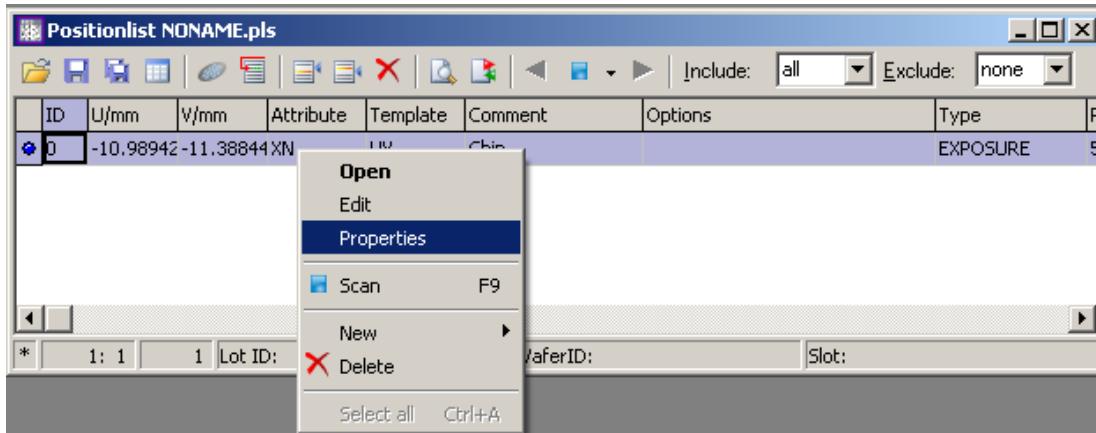


STEP 6 Layer 63 is the Manual markscan layer, represented by the brown boxes. Layer 61 is the Automatic markscan layer, represented by the small green rectangles.



STEP 7 Since these are layers in the GDSII file, they are executed in the same manner that an exposure is done. Open a “New” Positionlist and Drag-n-Drop the GDSII file “Chip” into the PLS. Select Layer 63.

STEP 8 Right-click on the line in the Positionlist and select “Properties”

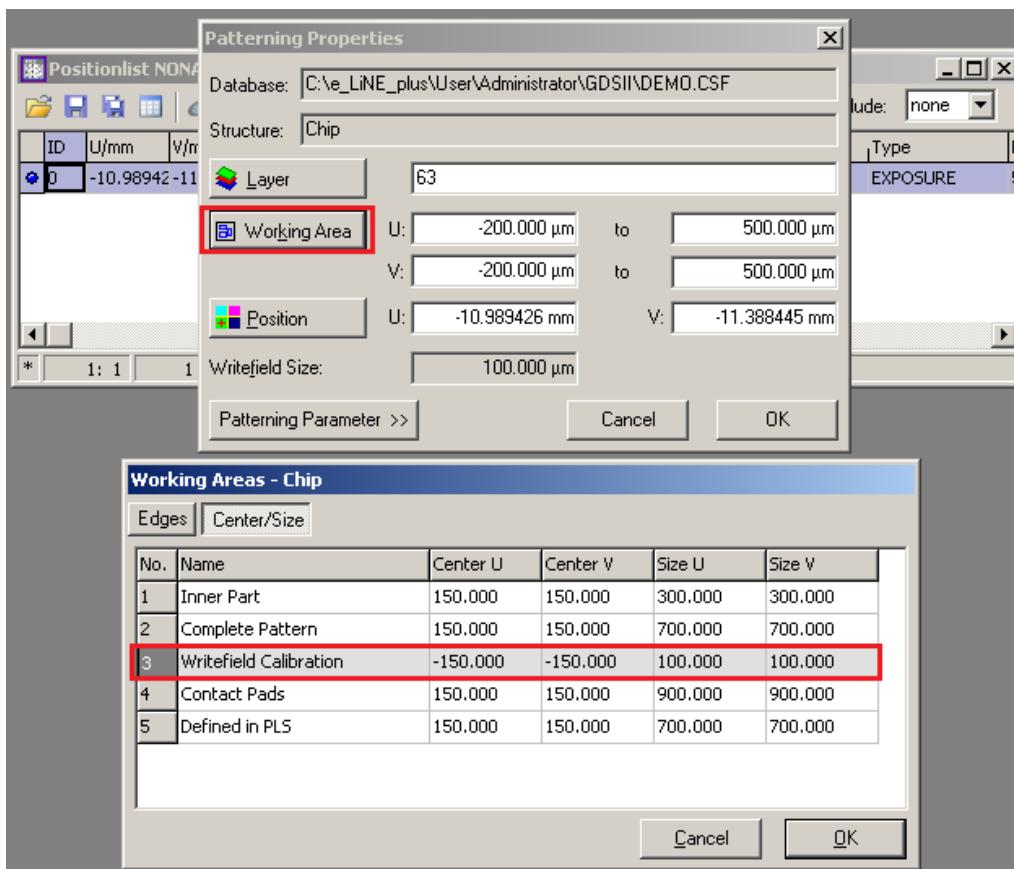


STEP 9 Right-click on the line in the Positionlist and select “Properties”

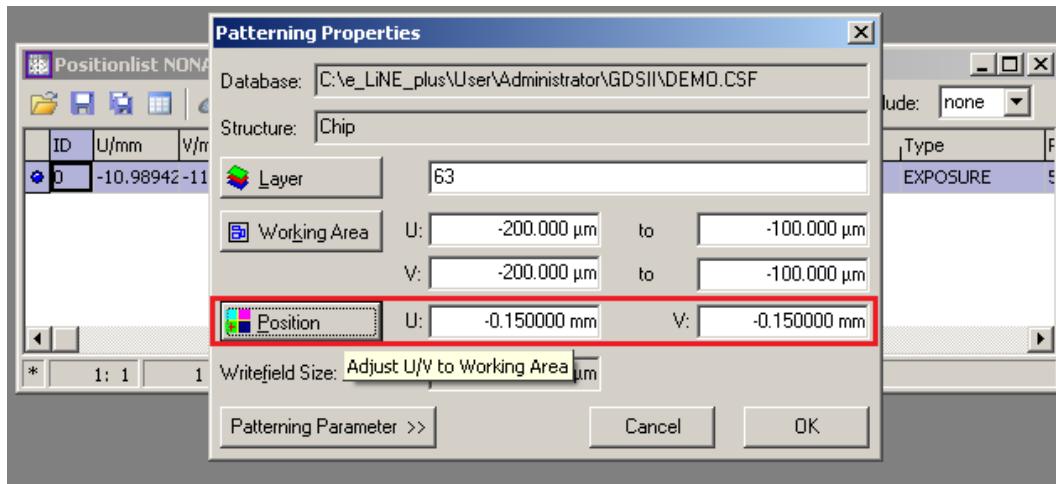
STEP 10 Select the Working Area and set it to “Writefield Calibration”.

HINT

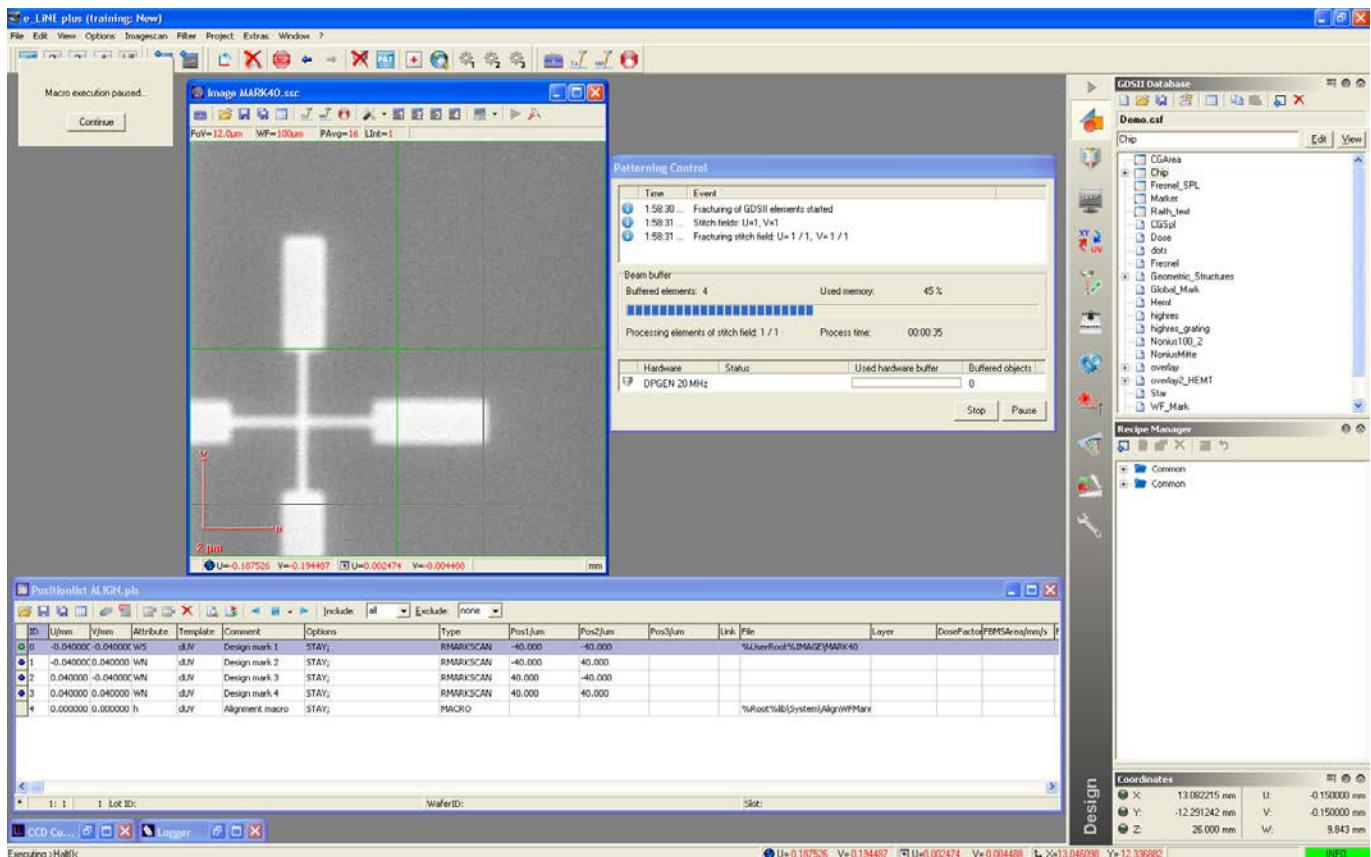
The concept of “working areas” is described in Tutorial 5 – Patterning. In this case here, we only wish to “expose” the Layer 63 marks that are in a 100 µm WF that surrounds one of the Global Marks. In this way, the software will only use these four marks to process the alignment of the writing field.



- STEP 12** Set the UV position to be the coordinates of the center of the Global Mark, i.e. the center of the working area that you have defined. You can press the “Position” button and the software will calculate the UV coordinates based on the working area definition.

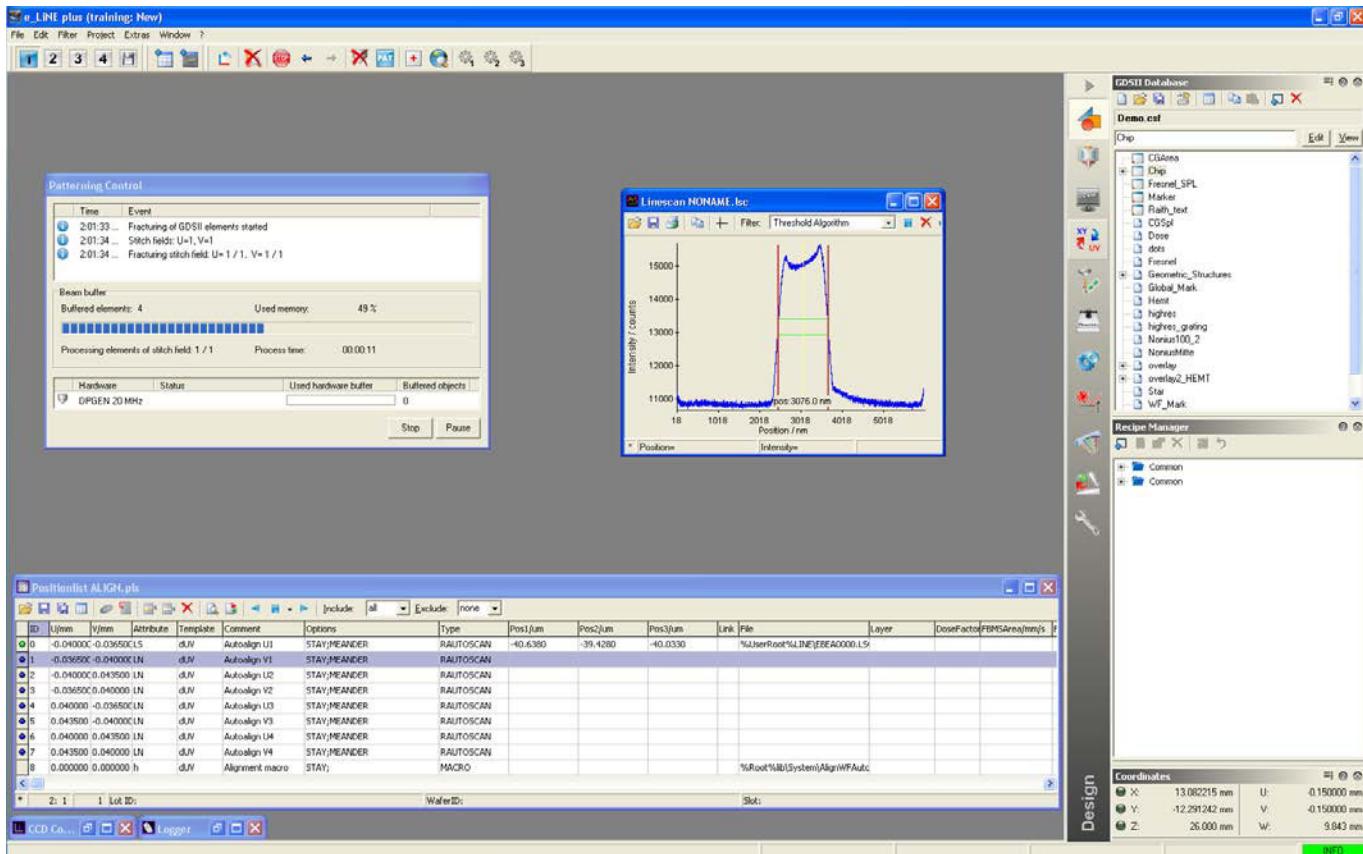


- STEP 13** Press “OK” and then execute the scan. The software will drive to the UV coordinates shown in “Position” and then the beam will deflect to the Manual marks scans that are in the executed scan, in this case 4 total marks will be scanned.



- STEP 14** Just as in Task 1 – Step 8, the green cross displayed in the center of the image defines the center location of the imagescan taken, where the cross is expected to be. As this is the first ALWF procedure, the cross will probably not be at the center of the imagescan, but the user can now define this position manually. To define the position of the cross, press the Ctrl key and the left mouse button together and hold while moving the mouse cursor to the required position, i.e. over top of the center of the cross. Once you have reached the new position, let go of the Ctrl button and the left mouse button and a blue cross will be displayed at the selected position.
- STEP 15** Click on the “Continue” button and the beam will move to the next UV position to perform the same cross alignment. Repeat these steps for each Manual markscan defined in the GDSII file.
- STEP 16** At the end of the procedure, a dialogue window will open and the writefield corrections has to be confirmed. Note the values for the Zoom, Shift, and Rotation in UV and confirm them if the values are acceptable.
- STEP 17** Now change the Layer to be patterned to Layer 61, for the automatic markscan layer, then execute the scan again. The stage will again move to address the UV coordinates that are listed in the Positionlist and the beam will then deflect and perform linescans at the defined positions shown in the GDSII file. Two linescans will be done at each mark, 1 in the horizontal and 1 in the vertical direction. The software will use these linescans to determine the location of the center of the cross.

HINT The adjustment of the Brightness/Contrast of the sample will affect the resulting linescan and therefore the alignment values that are determined from the Automatic markscan procedure. Care should be taken to set the levels appropriately to obtain a good linescan, demonstrated in the next image.

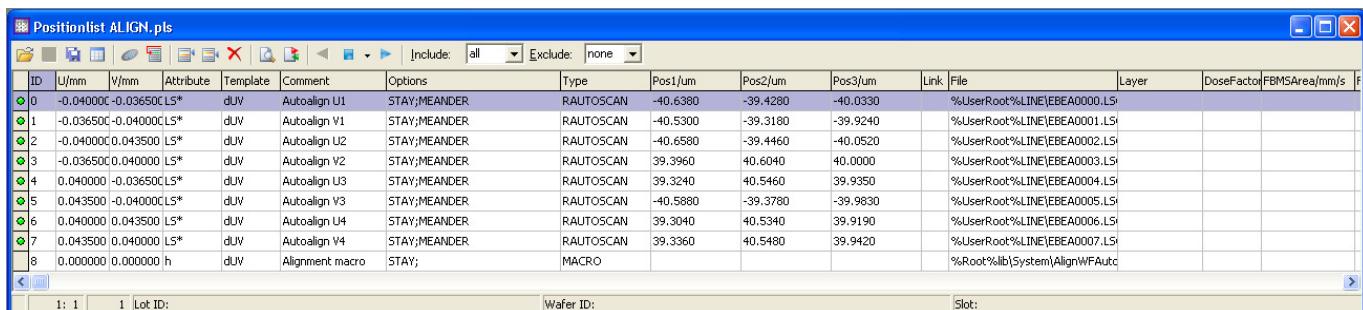


HINT

This is an automatic procedure. When finished, it will apply the calculated correction values to the AlignWriteField. There will be no prompting of the user to ask if the values are acceptable.

STEP 18

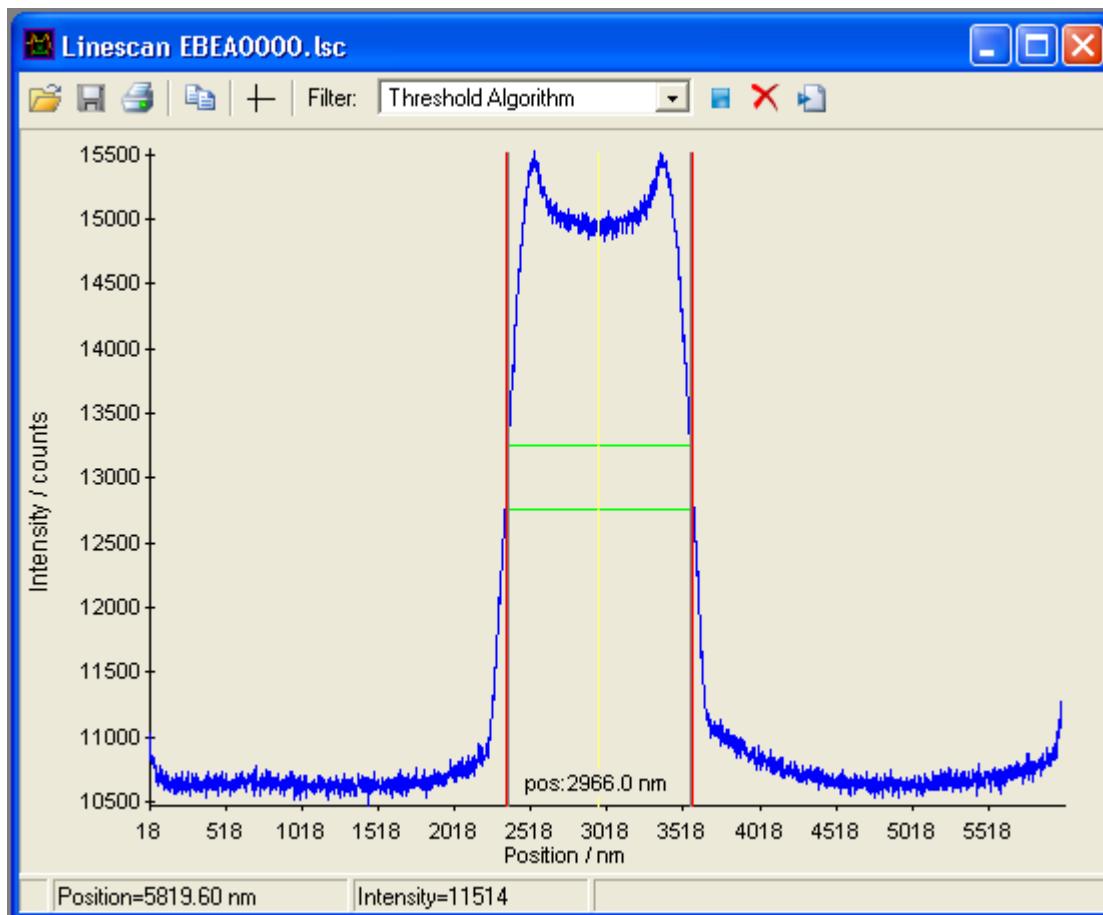
Open the Positionlist “Align.pls” (File/Open Positionlist). Whenever Layer 61 is executed by the software, the Positionlist “Align.pls” contains the linescans associated with the last execution of Layer 61.



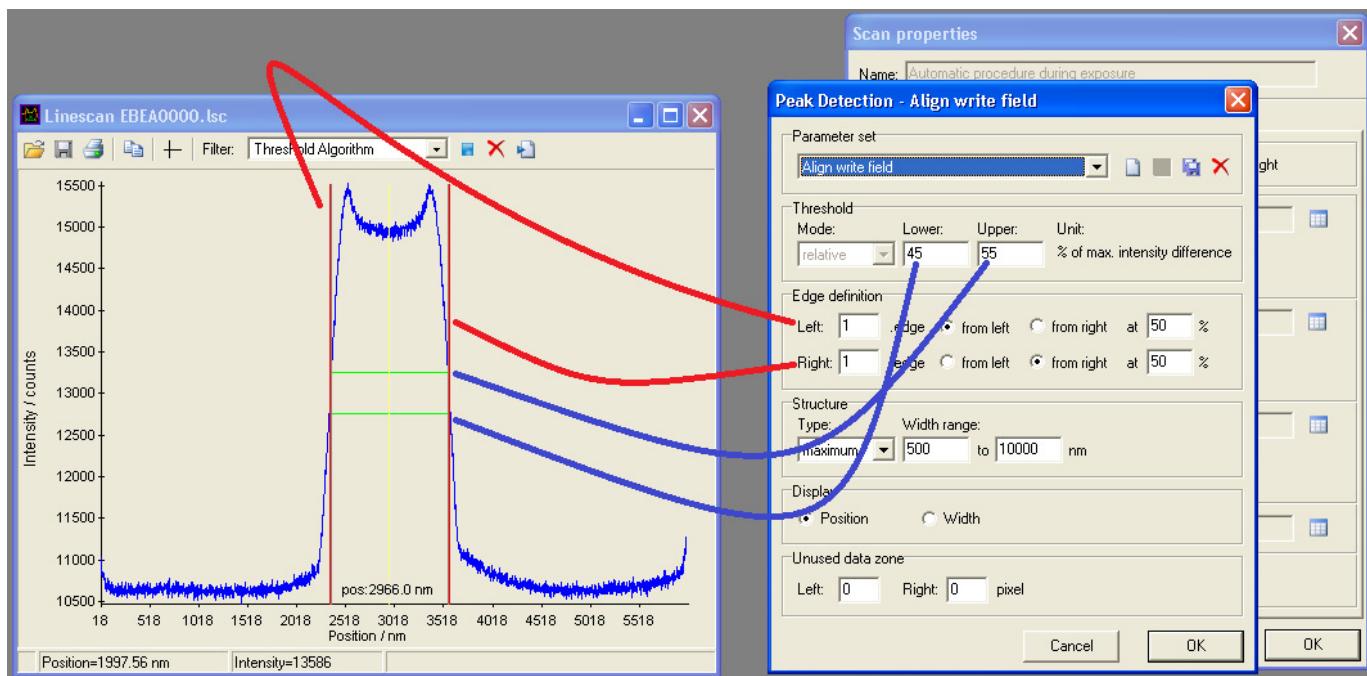
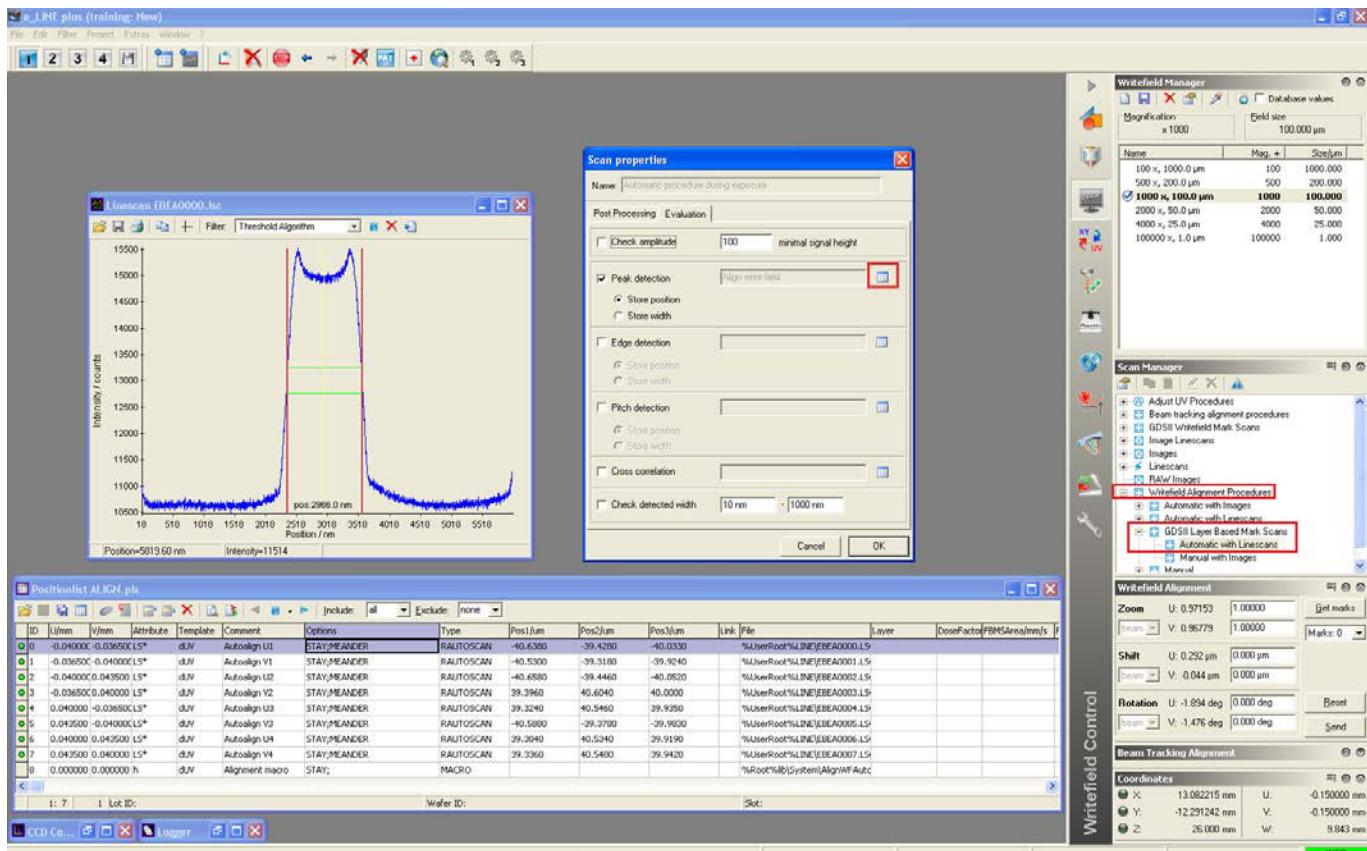
STEP 19

All linescans in the positionlist should have a “green” dot in front of them. This means that the structure scanned by the linescan fit with the parameters of the linescan algorithm and was detected.

STEP 20 If you double click on any of the linescans, it will open. This will allow the user to see how good the linescan algorithm was and if any adjustments to it or to the Brightness/Contrast need to be made.



STEP 21 The parameters of the algorithm are found in the Scan Manager, “GDSII Layer Based Mark Scans”. The user can choose to edit the “peak detection parameters.”



STEP 22 You are now ready to setup the overlay exposure.



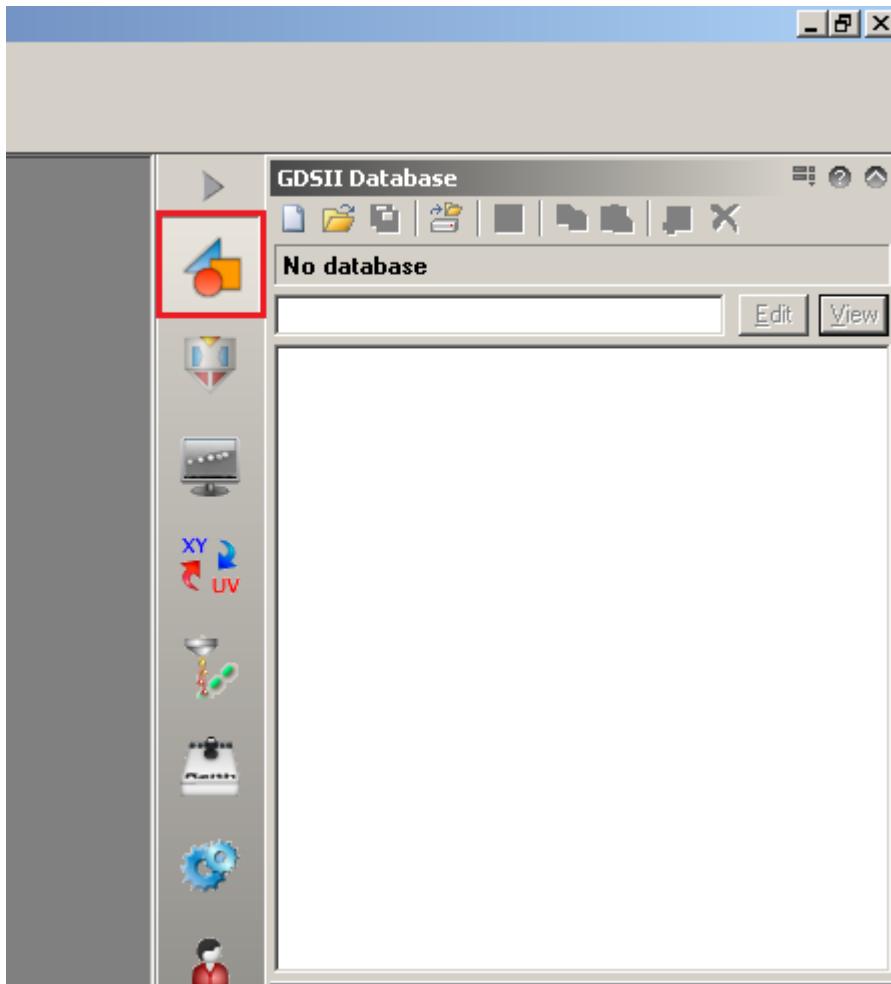
Raith Tutorial-5: Patterning

AIM The aim of this tutorial is to guide the user through the different steps to carry out the patterning of their sample.

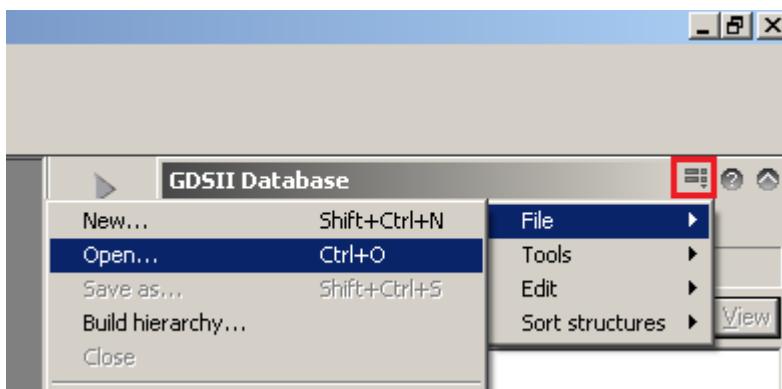
TASK 1:	Studying the existing pattern	60
TASK 2:	Setting up the lithography software	64
TASK 3:	Patterning	66
TASK 4:	Developing the sample	73
TASK 5:	Overlay patterning	75

TASK 1: Studying the existing pattern

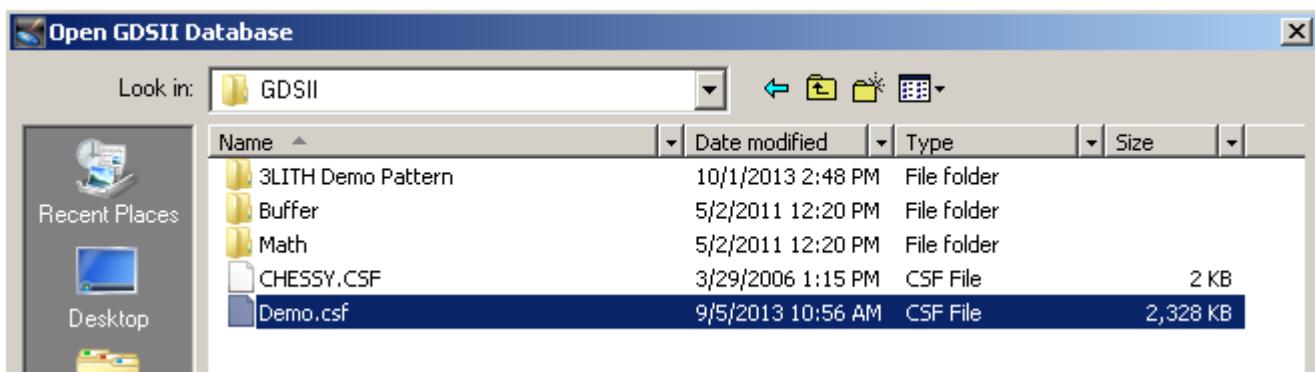
STEP 1 Click on the Design/GDSII Database window to activate it.



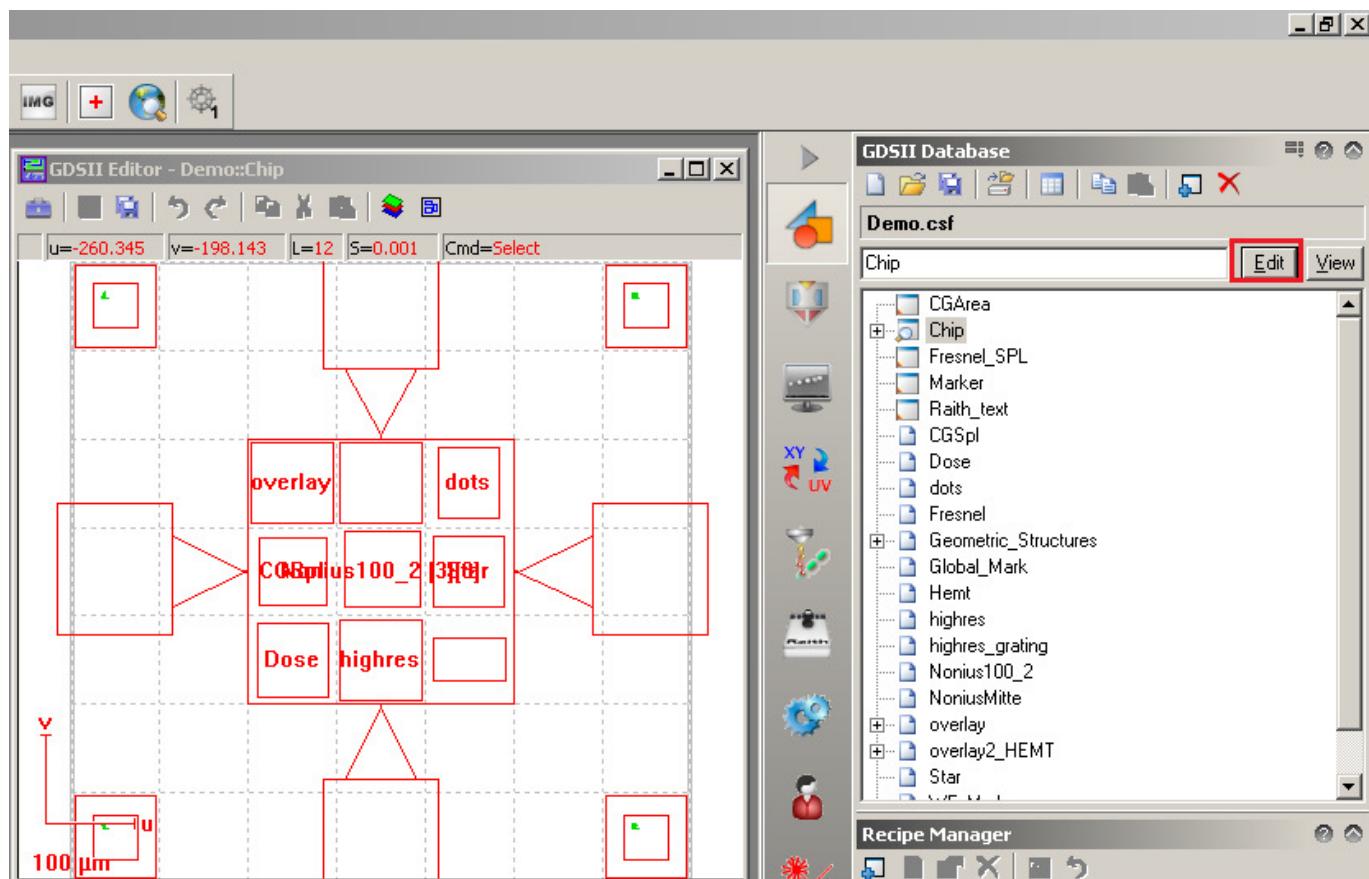
STEP 2 Select the Menu/File/Open from the drop-down list.



STEP 3 A dialogue box will open; select the Demo.csf pattern.

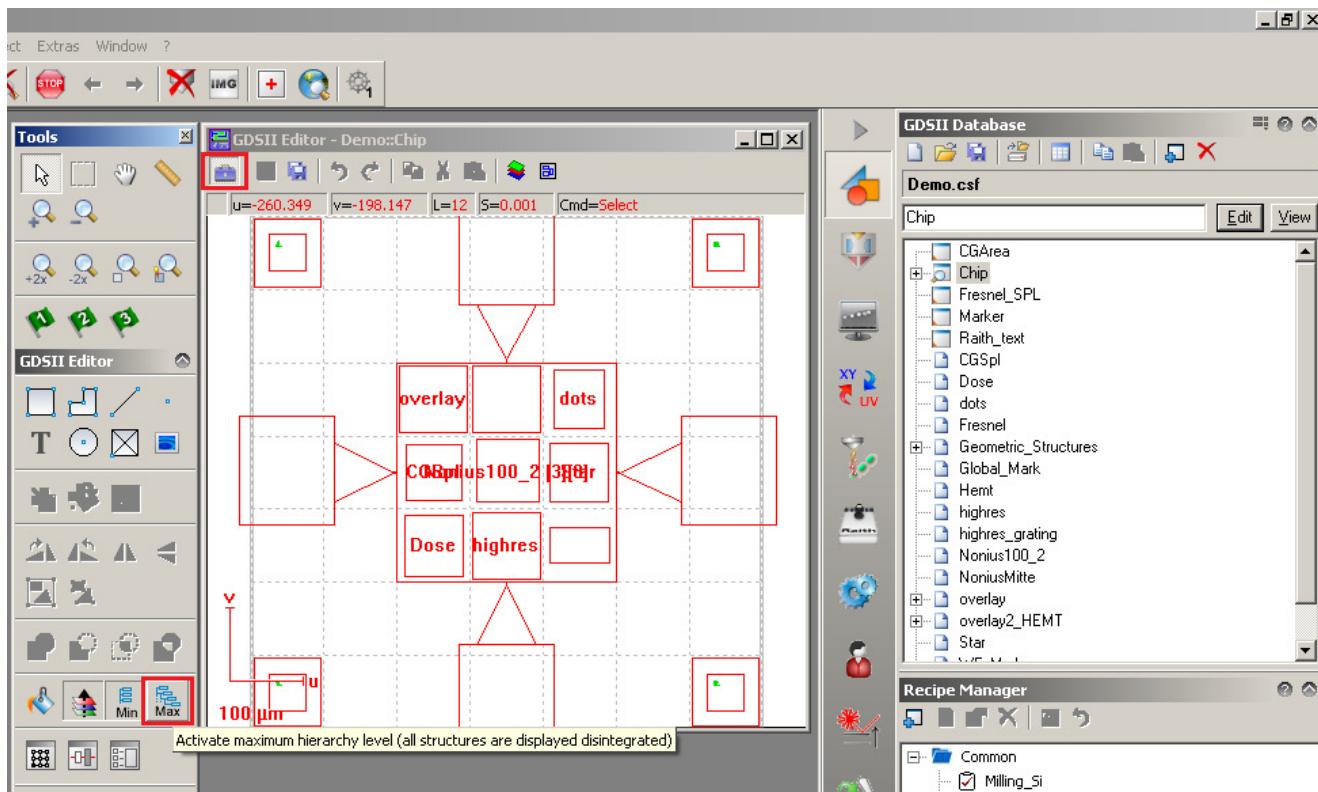


STEP 4 Select the pattern “Chip” and click on “EDIT”. The GDSII editor will now display the hierarchical structure of the selected pattern.

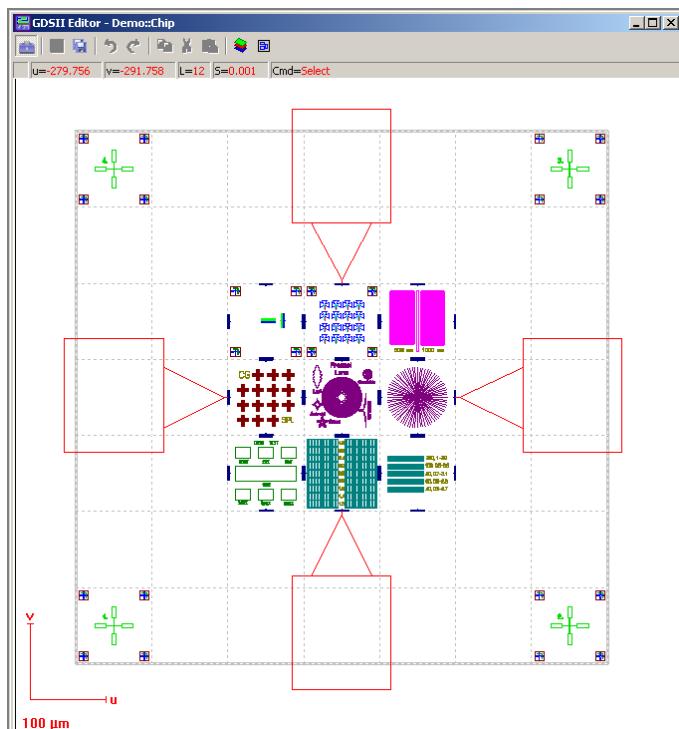


HINT In the “edit” mode, the user has the ability to change the pattern, create new structures, and obtain structure information. In “View” mode, the user can only see the pattern, but can do nothing to it.

STEP 5 Select the Toolbox and set the hierarchy of the pattern to Max.



STEP 6 The full structure of the pattern is now displayed, showing various test patterns and alignment markers.

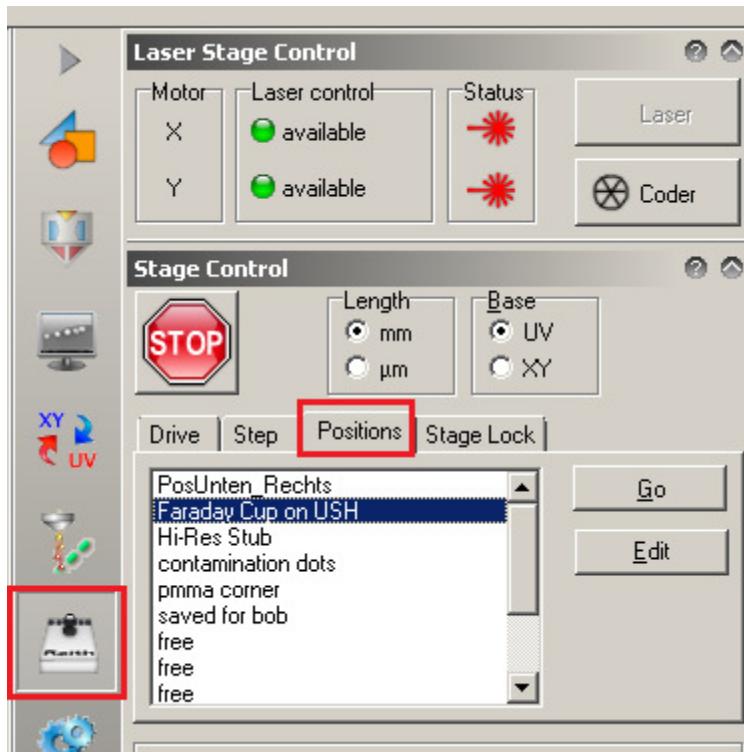


HINT

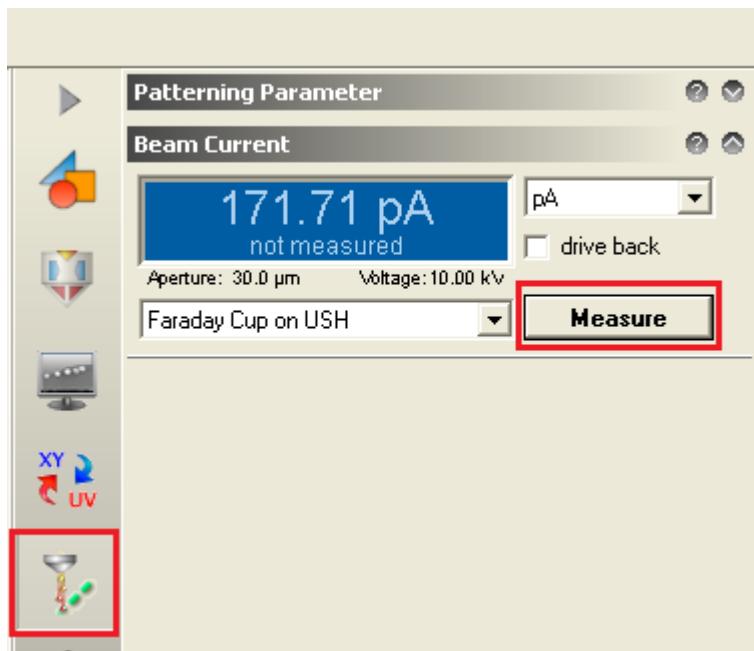
For more detail on the pattern and the different structures in the Demo pattern, refer to the documents “Raith_Demo_pattern_description_2014.pdf” and “Raith_Demo_Pattern_2013.pdf”.

TASK 2: Setting up the lithography software

STEP 1 Using the Stage Control window, drive the system to the Faraday cup.

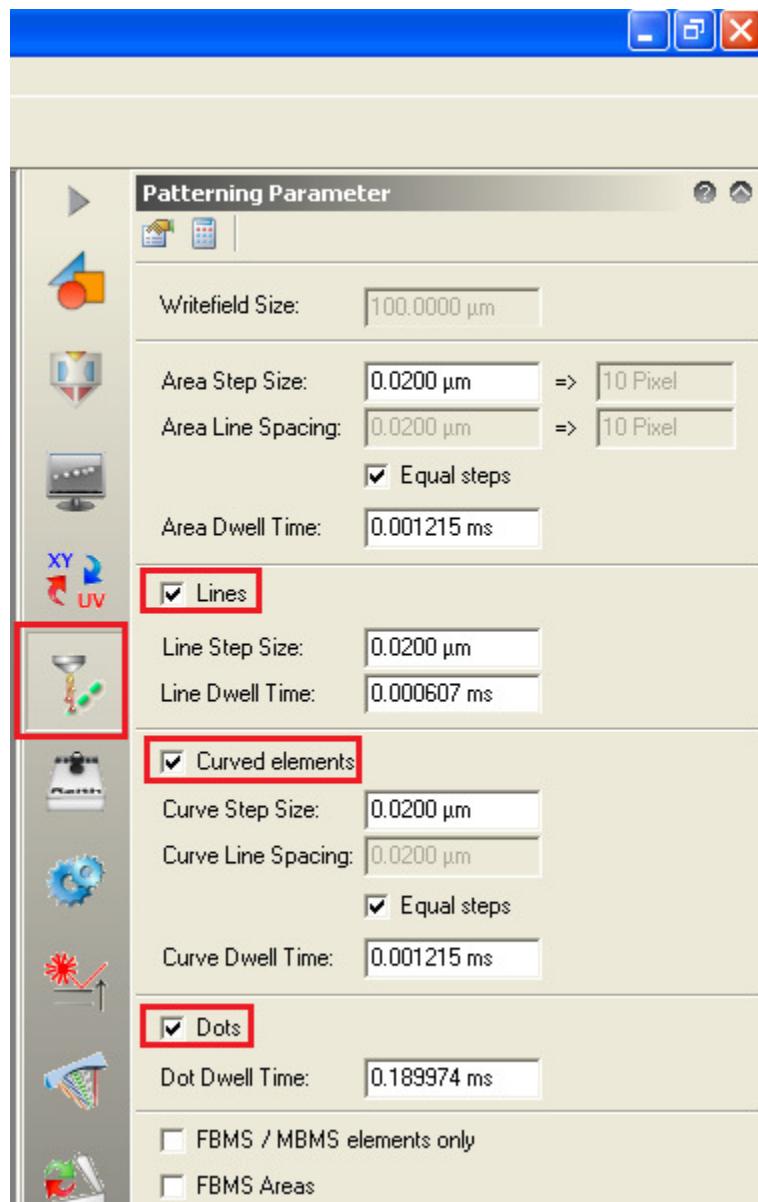


- STEP 2** Toggle the beam blanker to switch on the beam and obtain an image in the Column software. Make sure that the Faraday cup is in the center of the image. If necessary, fine tune the position manually by using the joystick.
- STEP 3** Select the Beam Current window and press the “Measure” button.



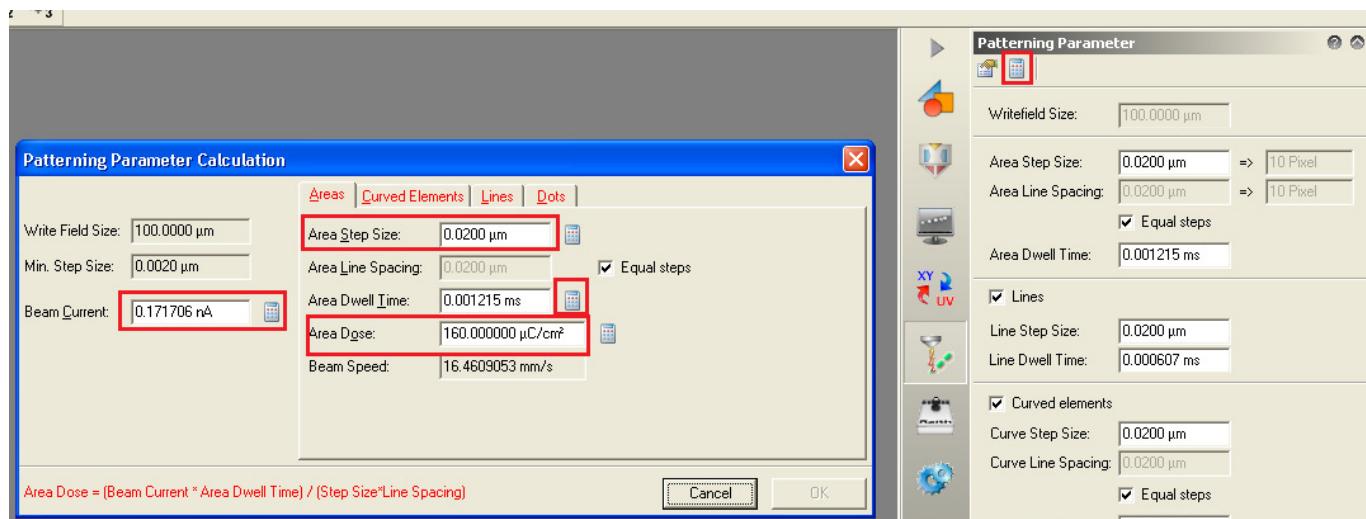
TASK 3: Patterning

STEP 1 Select the Patterning window and confirm the elements of the GDSII file for patterning, i.e. select “Lines”, “Curved elements” and “Dots” for the Demo pattern.



HINT “Areas” are always selected by default.

STEP 2 Press the Calculator button.



HINT The measured Beam Current should appear in the “Beam Current” of the Calculator window. For each element (Areas, Curved elements, Lines, and Dots) there are different tabs. At the bottom of the Calculator window, a formula is displayed for the corresponding tab. After each parameter, there is a “calculator” button to be used to re-calculate the corresponding parameter.

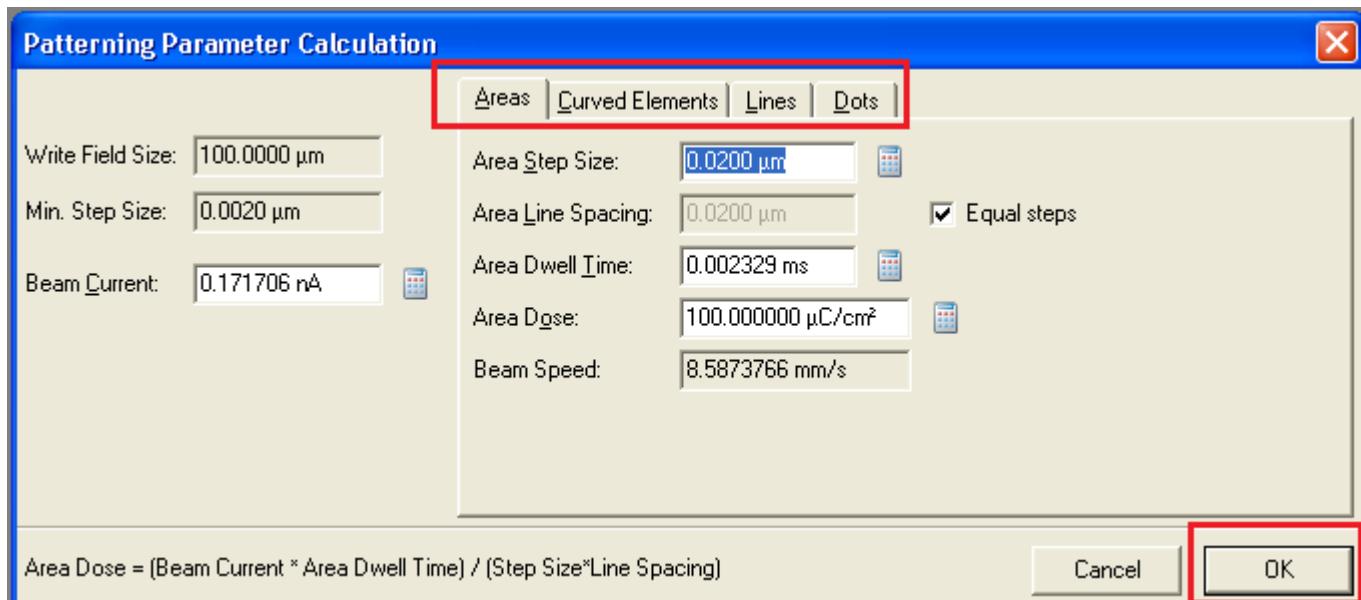
STEP 3 For each tab, the user must enter the parameters for the patterning, which depends on the process. For example, if using the resist PMMA, 950k molecular weight, 100 nm in thickness, and an acceleration voltage of 10 kV, the Area dose would be 100 µC/cm².

HINT Until the user has entered the appropriate values for the different parameters, the tab will normally be shown in RED. Once the values are set correctly (corresponding to the hardware that is connected), the tab color will switch to BLACK. Once all tabs have been properly defined, the OK button will be enabled.

STEP 4 Put in the following parameters for each of the elements in the calculator. After inputting the values, press the calculator button next to the “dwell time” for each tab.

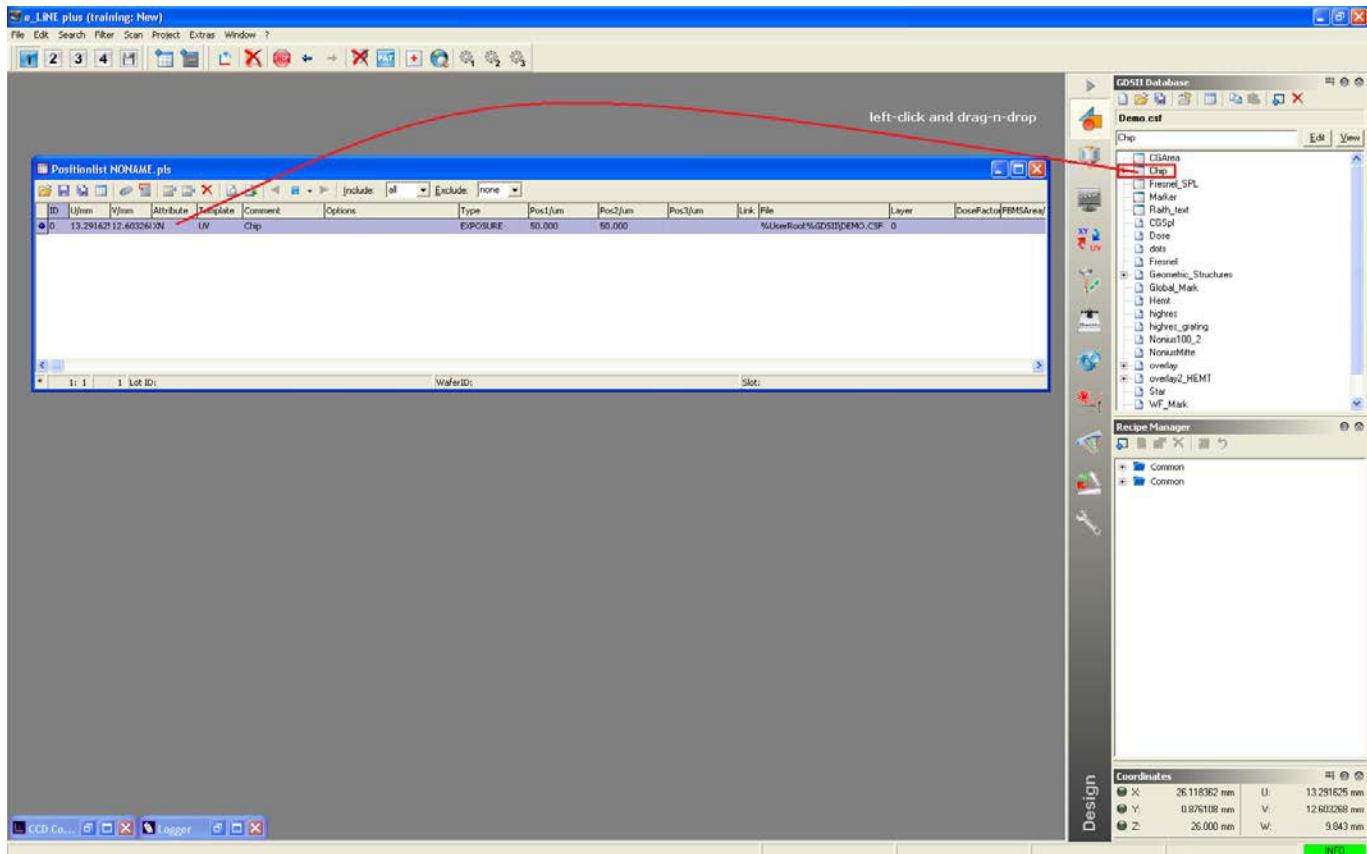
Area dose	100 µC/cm ²
Area step size	20 nm (equal steps for both UV)
Curved element dose	100 µC/cm ²
Curved element step size	20 nm
Curved element line step size	20 nm

Line dose	300 pC/cm
Line step size	10 nm
Dot dose	0.1 pC

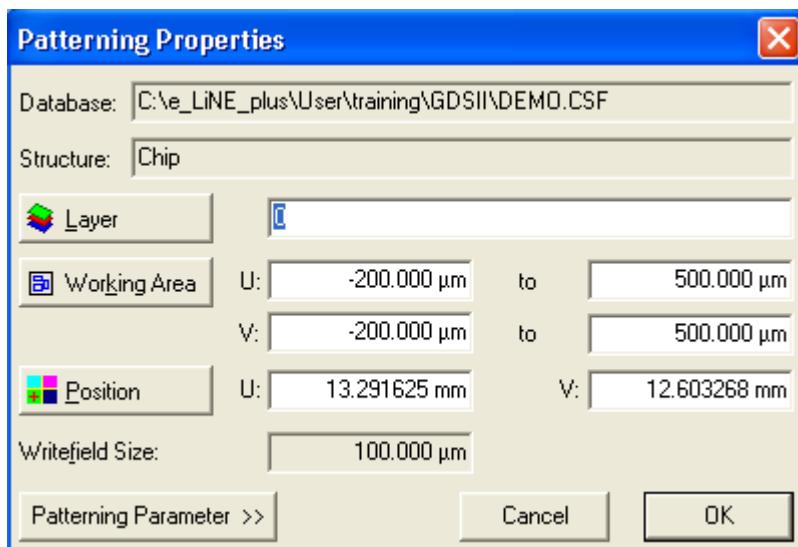


STEP 5 Press OK.

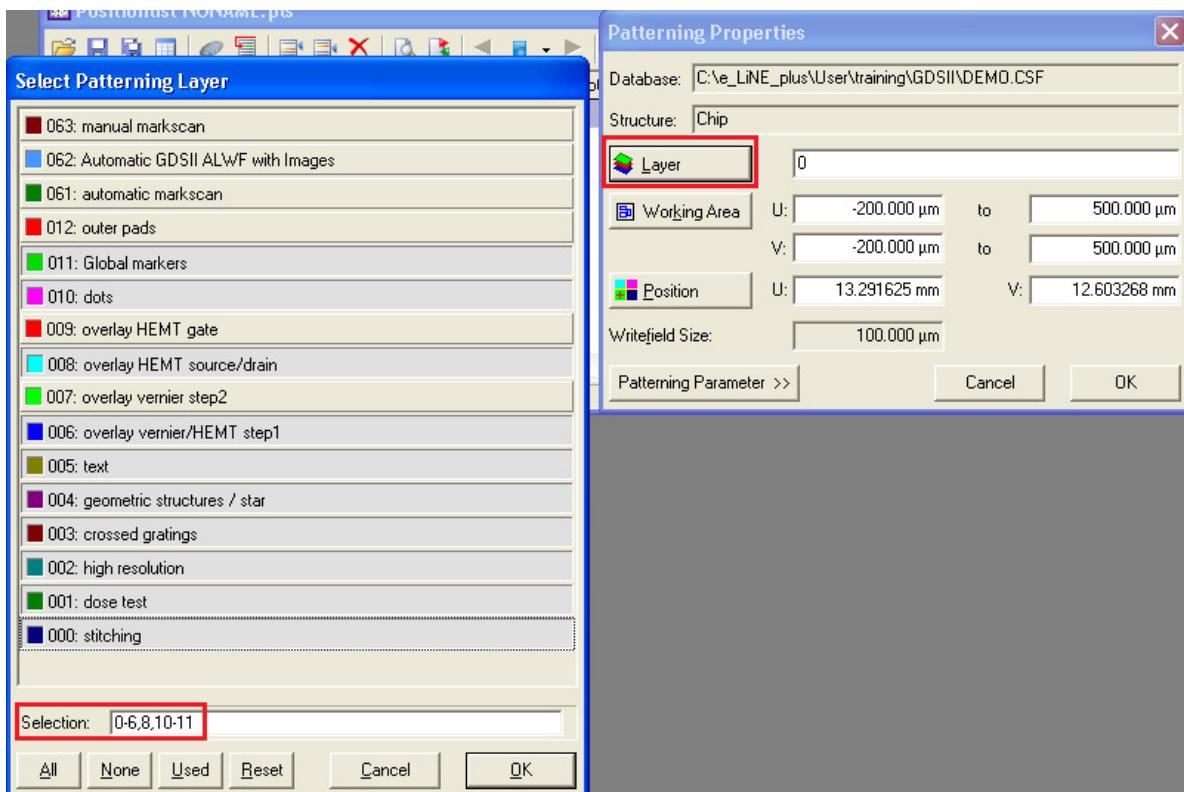
STEP 6 Open a NEW Positionlist. From the Design/GDSII database window, left-click on “Chip” and drag-n-drop it into the Positionlist.



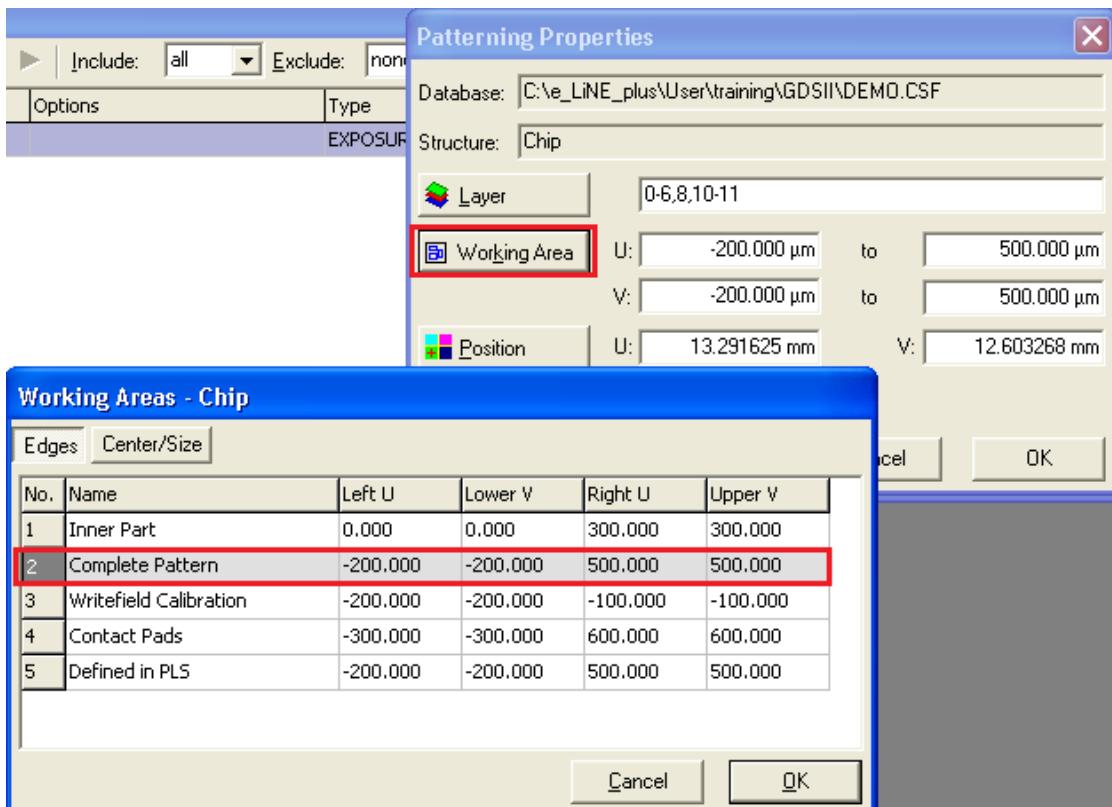
STEP 7 Right-click on the line in the Positionlist and select “Properties”.



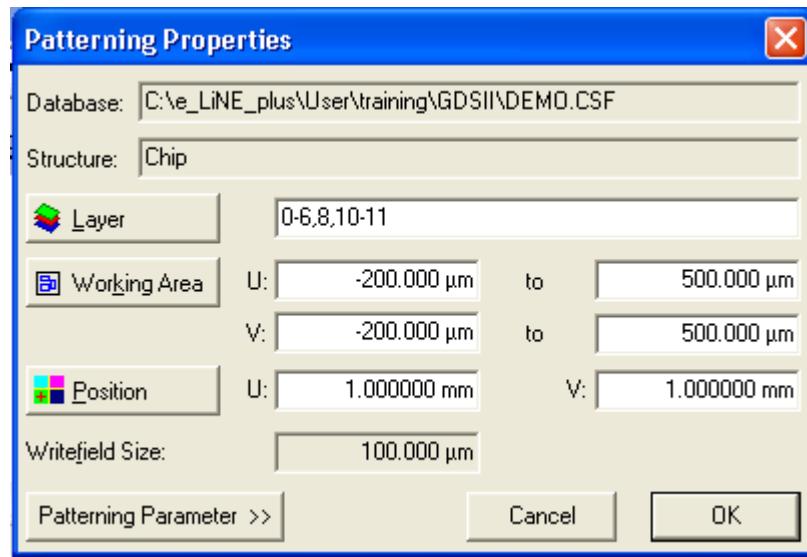
STEP 8 Select the “Layer” button to define the layers of the pattern that will be written. For this first patterning, choose Layers 0-6, 8, 10-11.



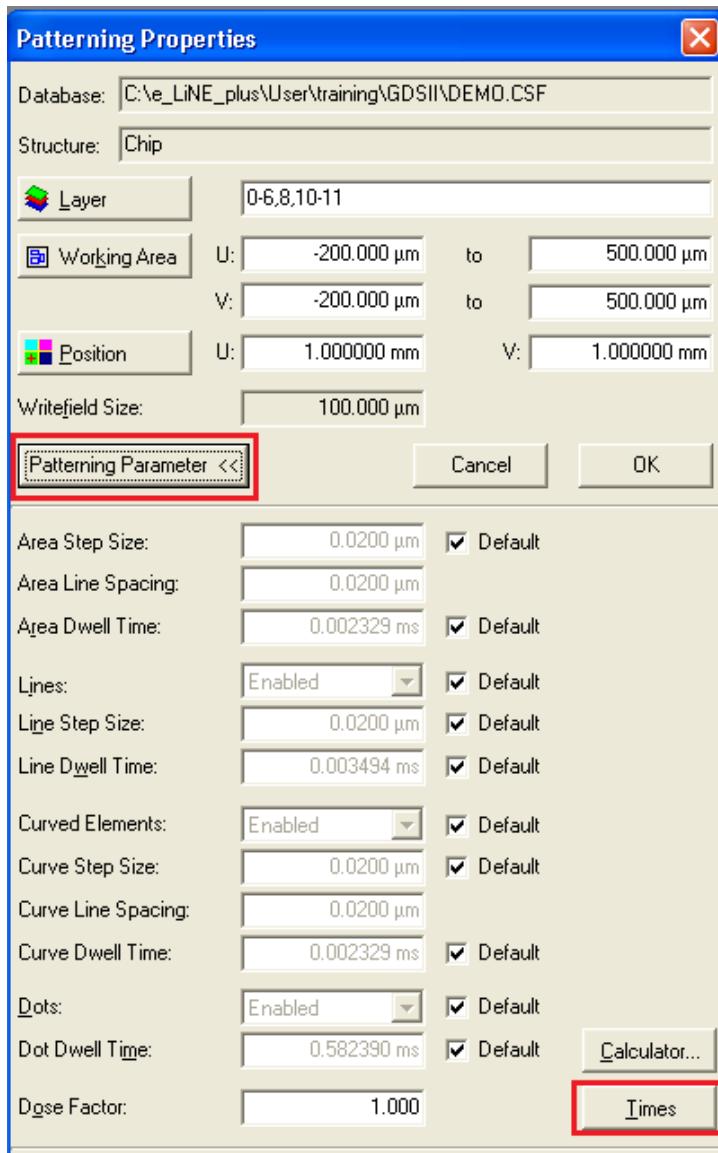
STEP 9 Select the “Working Area” button to define the Area of the GDSII file that will be patterned. For this first write, choose “Complete Pattern”.



STEP 10 By default, the “Position” of the exposure is set to the current stage coordinates when the GDSII file is drag-n-drop into the Positionlist. The next step is to change the exposure position to the desired location, with respect to the Global coordinate system that the user has established. Assuming that your sample has a UV coordinate range between UV=0 and UV=10 mm, the first exposure could be set at U=1 and V=1 mm. Enter the position to U=V=1 mm.



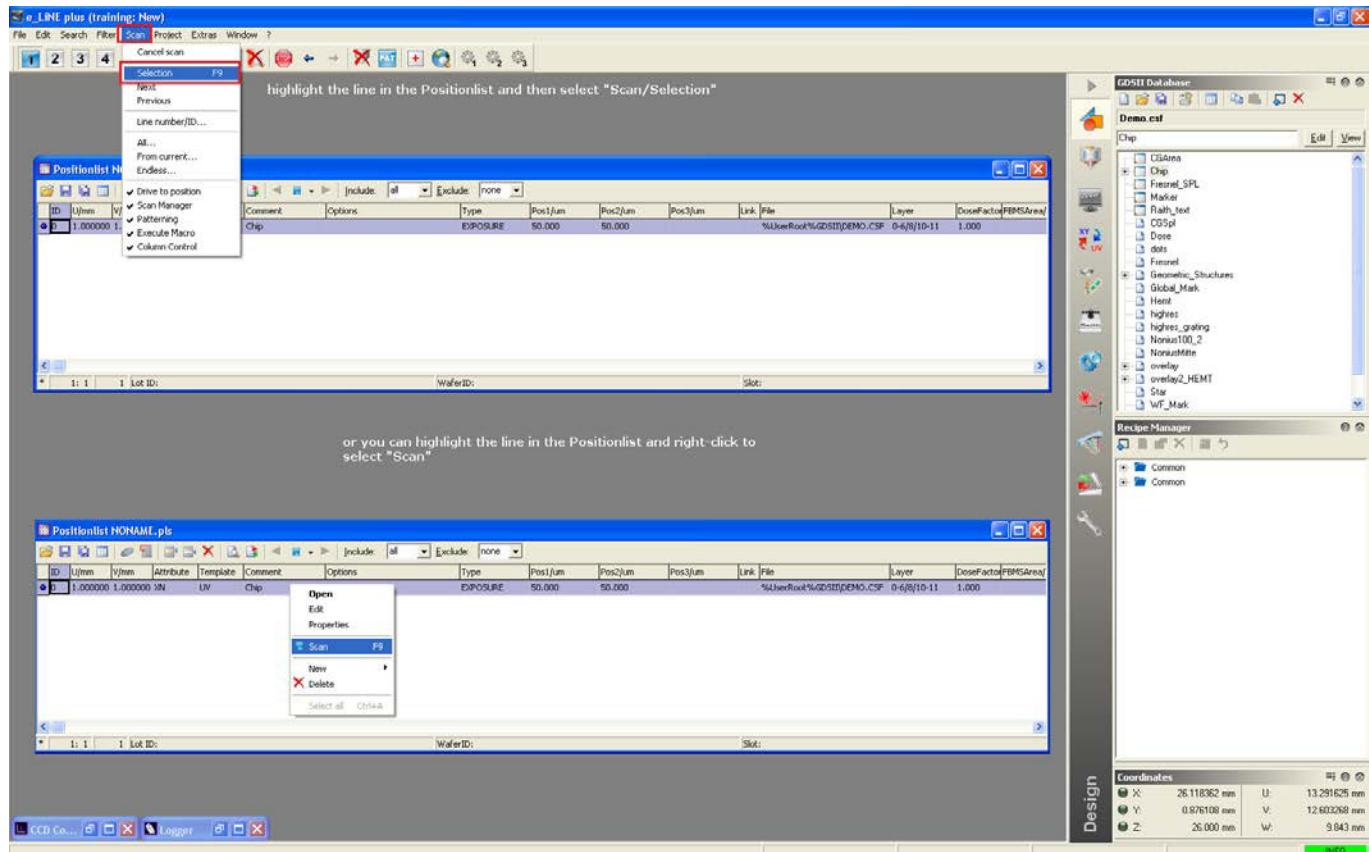
STEP 11 It is possible to get an estimate of how long the patterning will take by doing a “times” calculation. Select the “Patterning Parameters” button to expand the window. Then press the “Times” button. A new window will appear with the estimated time for the patterning.



Estimated Patterning Times		
Function	Time / s	
Dwelltime	1min 42.40s	
Settling time	30.83s	
Stage move time	7.80s	
Stage settling time	6.00s	
Transfer time	3.30s	
Alignment time	0.00s	
-----	-----	-----
Total time	2min 30.32s	
Calculation time	12.88s	
-----	-----	-----
Macro execution time not included		
Macros	28	
		OK

STEP 12 Press “OK”, then press “OK” again.

STEP 13 Highlight the Positionlist and execute the line.

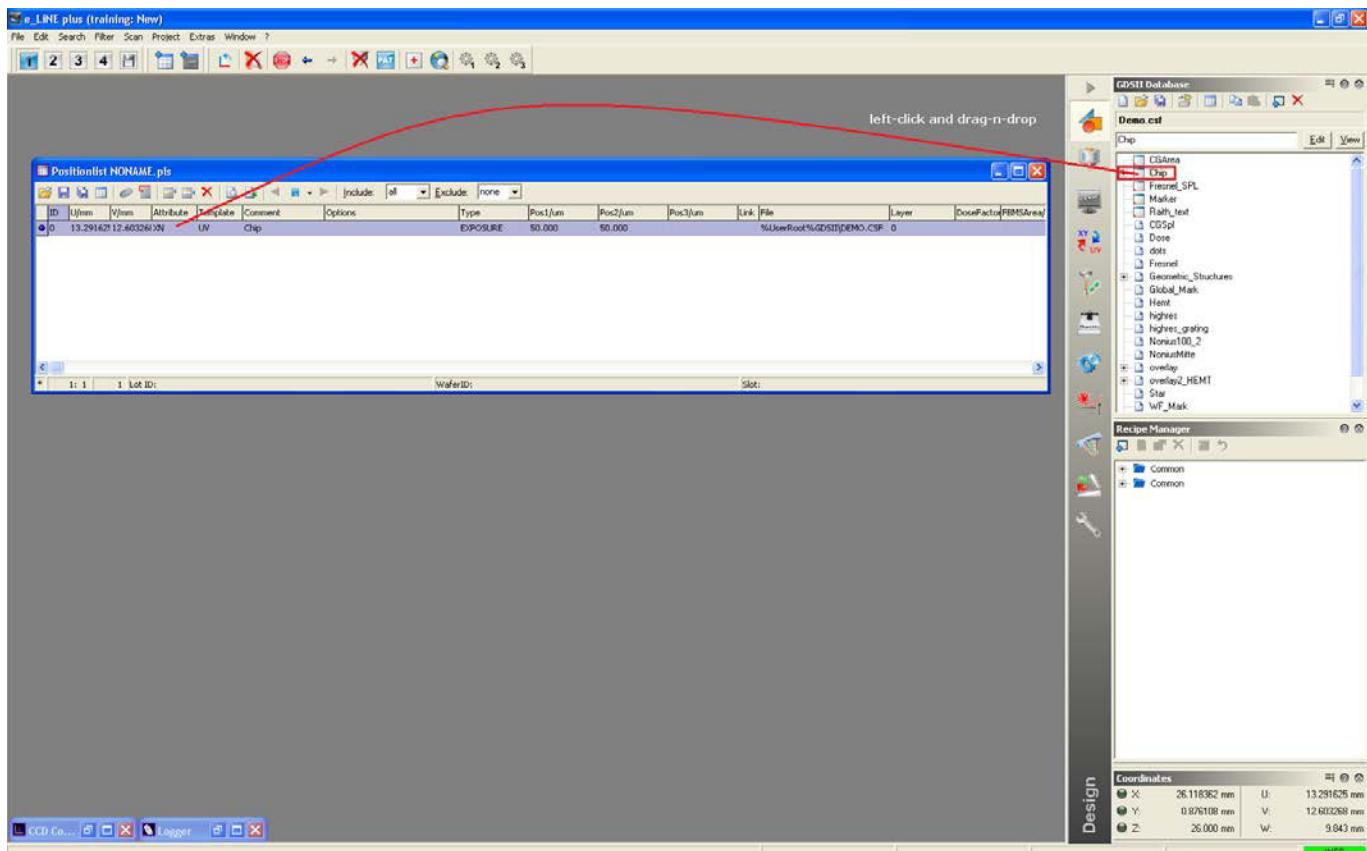


TASK 4: Developing the sample

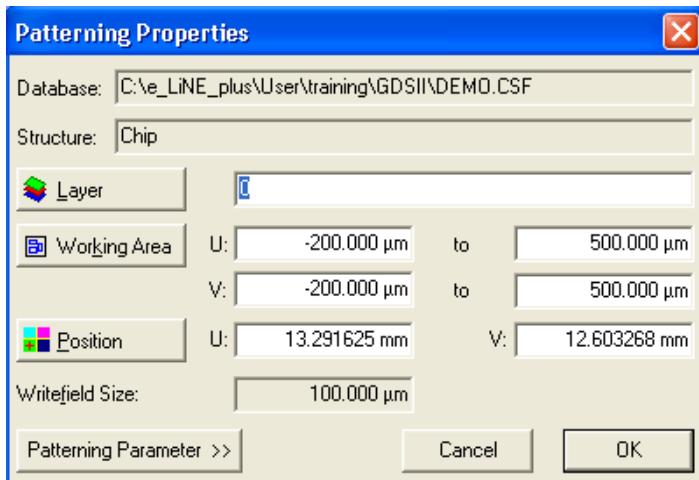
- STEP 1** Unload the sample.
- STEP 2** Develop the resist according to its type. In this case, we have assumed the user is working with PMMA, 950k. Develop the sample in a mixture of MIBK:Isopropanol (1:3 ratio) for 30 seconds and rinse in pure isopropanol for 30 seconds. Blow dry the sample with Nitrogen.
- STEP 3** After initial inspection with an optical microscope, reload the sample into the system. Re-establish the same Global coordinate system and then navigate to find your pattern. In the example above, this was at U=V= 1 mm.

TASK 5: Overlay patterning

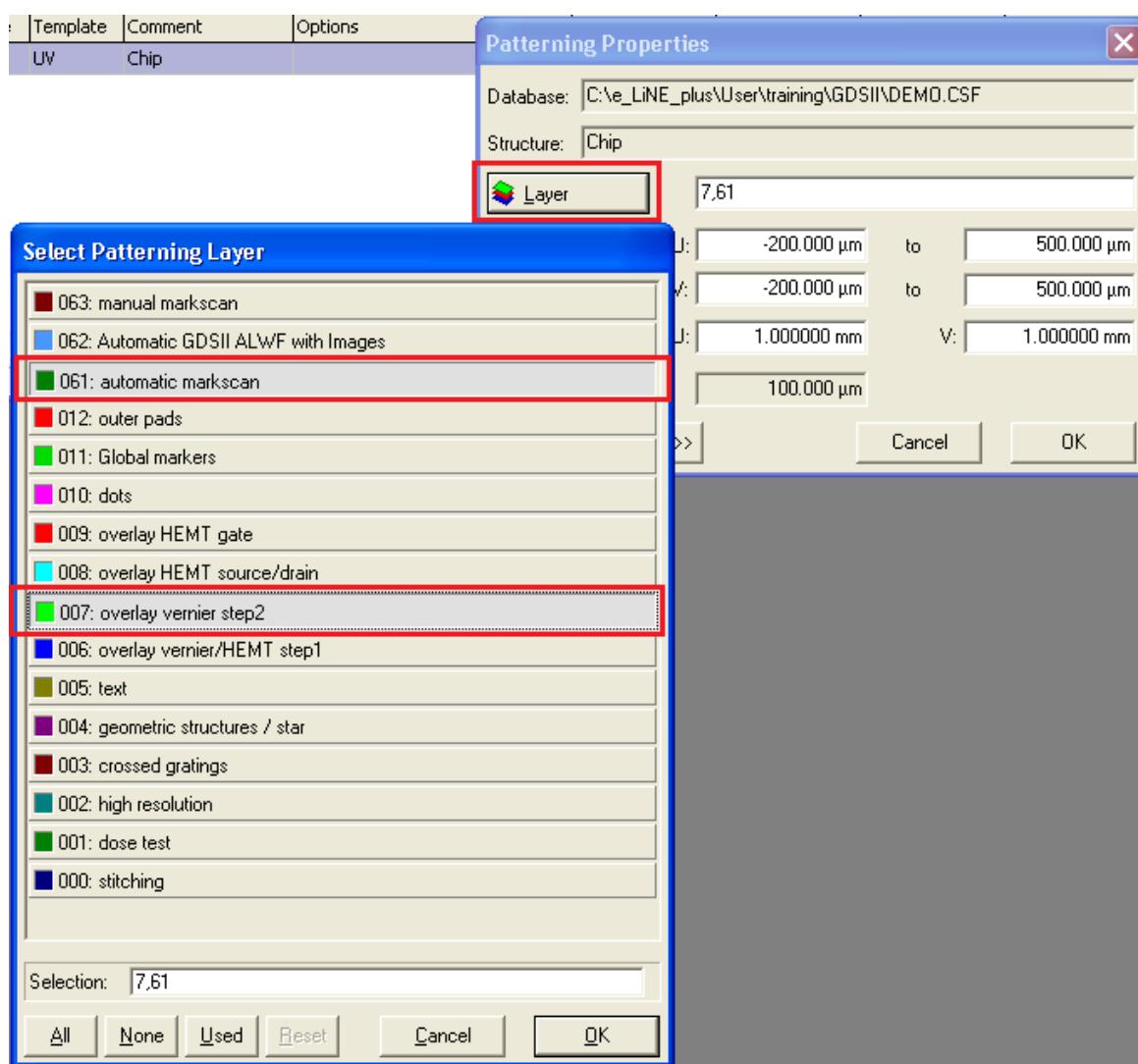
- STEP 1** In the previous Tutorials 3 and 4, it was explained how to establish a 3-point Local coordinate system to the first level patterning and also how to process the align writefield to this existing pattern using Layers 63 and 61. The following steps assumes you have already done all of those steps.
- STEP 2** Drive to the Faraday cup and measure the beam current.
- STEP 3** Set up the Calculator. Use the same settings as in the previous Task, Patterning.
- STEP 4** Open a New Positionlist.
- STEP 5** Open a NEW Positionlist. From the Design/GDSII database window, left-click on “Chip” and drag-n-drop it into the Positionlist.



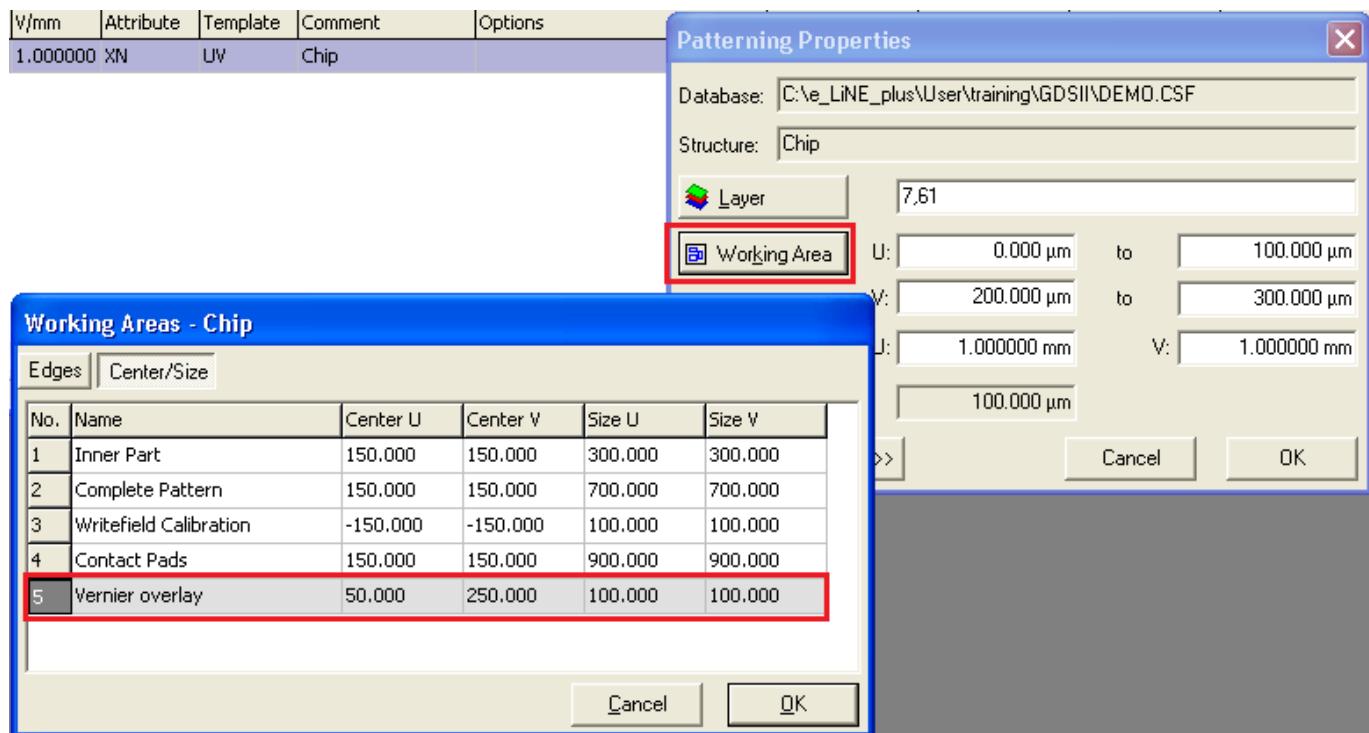
- STEP 6** Right-click on the line in the Positionlist and select “Properties”.



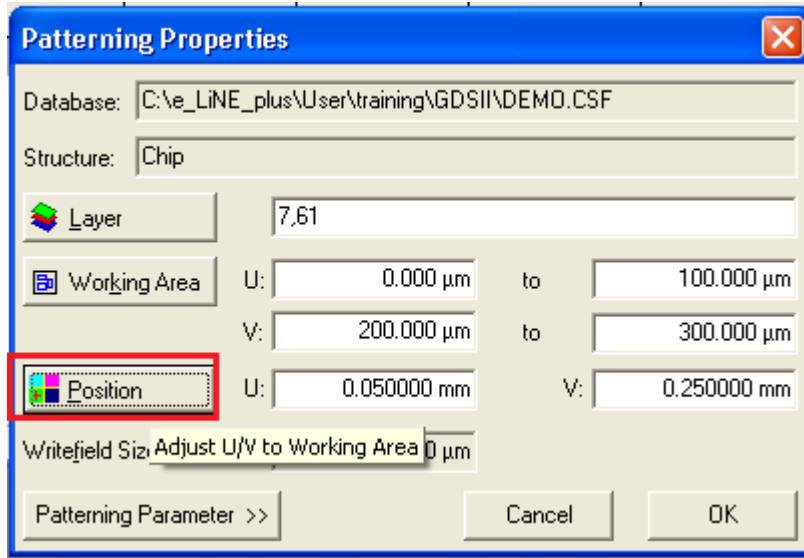
STEP 8 Select the “Layer” button to define the layers of the pattern that will be written. For this overlay patterning, the user should select Layers 61 and 7, the Vernier overlay structure.



STEP 9 Select the “Working Area” button to define the Area of the GDSII file that will be patterned. For this overlay, if a working area does not already exist for the “Vernier overlay”, the user will have to create one in the GDSII editor (see Tutorial 6 – Pattern generation).



STEP 10 By default, the “Position” of the exposure is set to the current stage coordinates when the GDSII file is drag-n-drop into the Positionlist. The next step is to change the exposure position to the desired location, this time with respect to the 3-point Local coordinate system that the user has established. In this case, since the working area is equal to the writefield size we are using (100 µm), the user can select the “Position” button and the software will calculate the coordinates based on the defined working area, in this case, U = 50 µm, V = 250 µm.



STEP 11 Press “OK”.

STEP 12 Scan the Positionlist. The software will drive the stage to the UV position and then first pattern Layer 61, the automatic markscan layer. Once this is completed, Layer 7 will be patterned.

HINT There is also an overlay pattern for the HEMT field. The user will need to define a new working area in the GDSII design, if not already done so, to encompass only this 100 mm working area, i.e. centered at U = 150 mm, V = 250 mm. Repeat Steps 5 – 12 to pattern this overlay. The Layers for this patterning will be Layers 61 and 9.

STEP 13 Unload sample, develop as before , and inspect optically and then reload to inspect with the system.



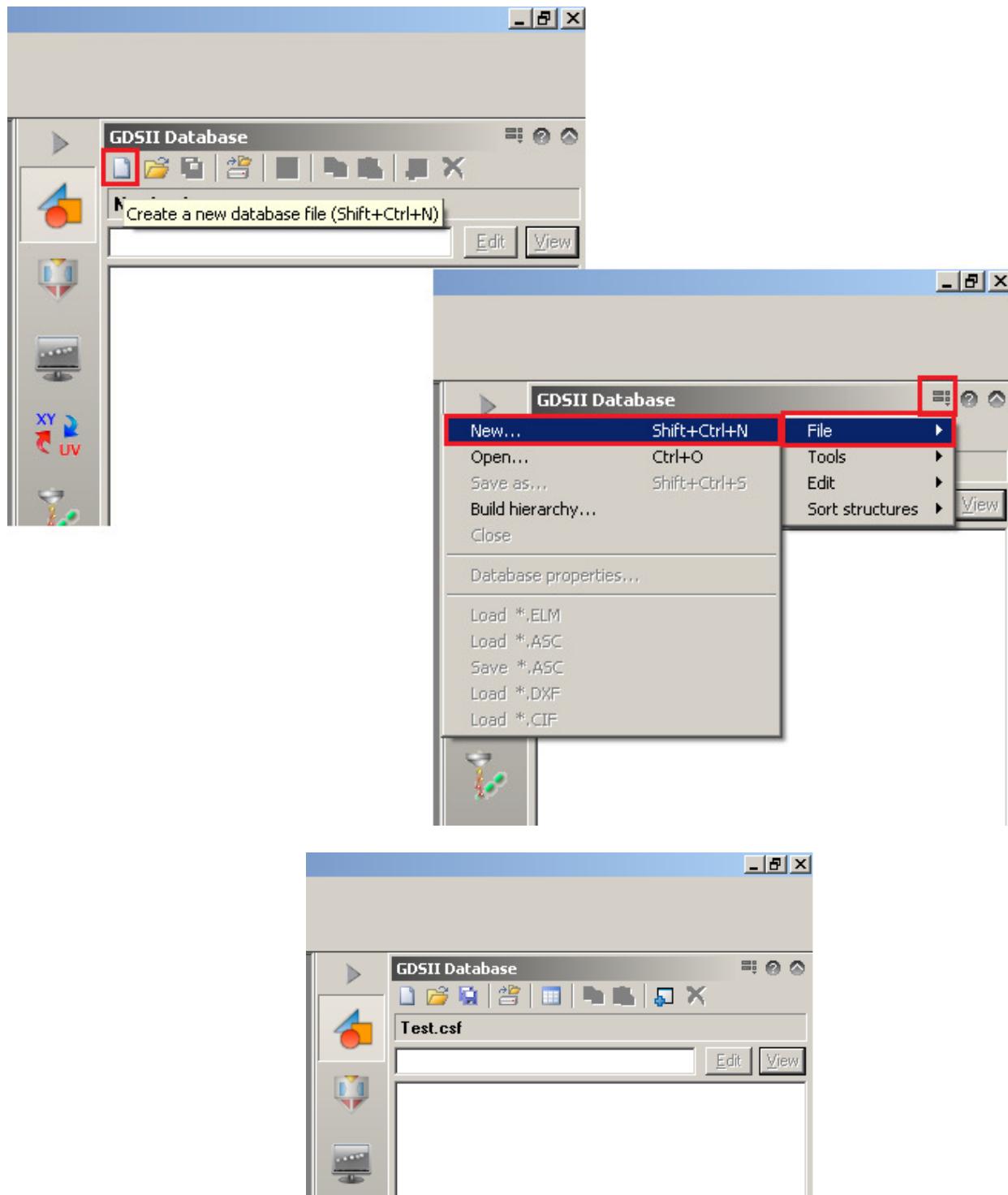
Raith Tutorial-6: Pattern Generation

AIM This Tutorial gives an overview of the different design features by using the internal GDSII editor. It is also possible to import a pattern from other editors, such as AutoCAD™, but it is recommended to use the internal editor, mainly because it allows you to assign a different dose to each feature in each GDSII layer.

TASK 1:	Creating a design field for a new structure within a new database	81
TASK 2:	Feature design via toolbox and digital modification	84
TASK 3:	Multiplying structures	87
TASK 4:	Using different layers	93
TASK 5:	Saving, deleting, and copying of structures/databases	96

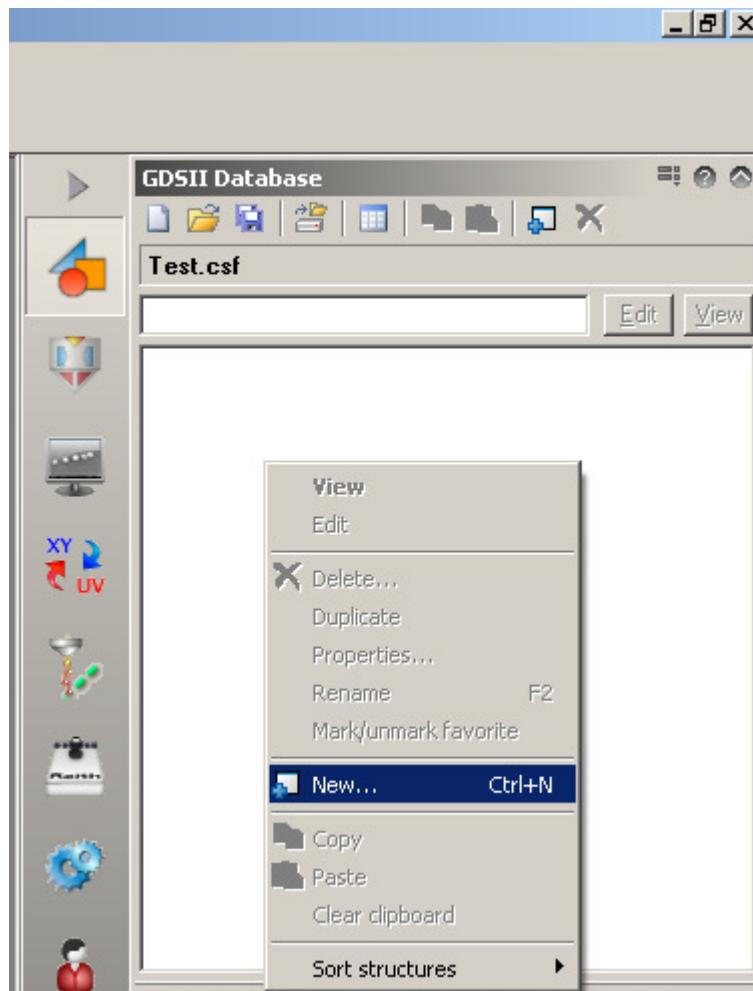
TASK 1: Creating a design field

STEP 1 Activate the GDSII database window, click on File and select New from the dropdown list box. A dialogue box will open where you can create a new database within any folder, e.g. with the name "Test". After saving you will get an empty GDSII Database with the name "Test.csf".



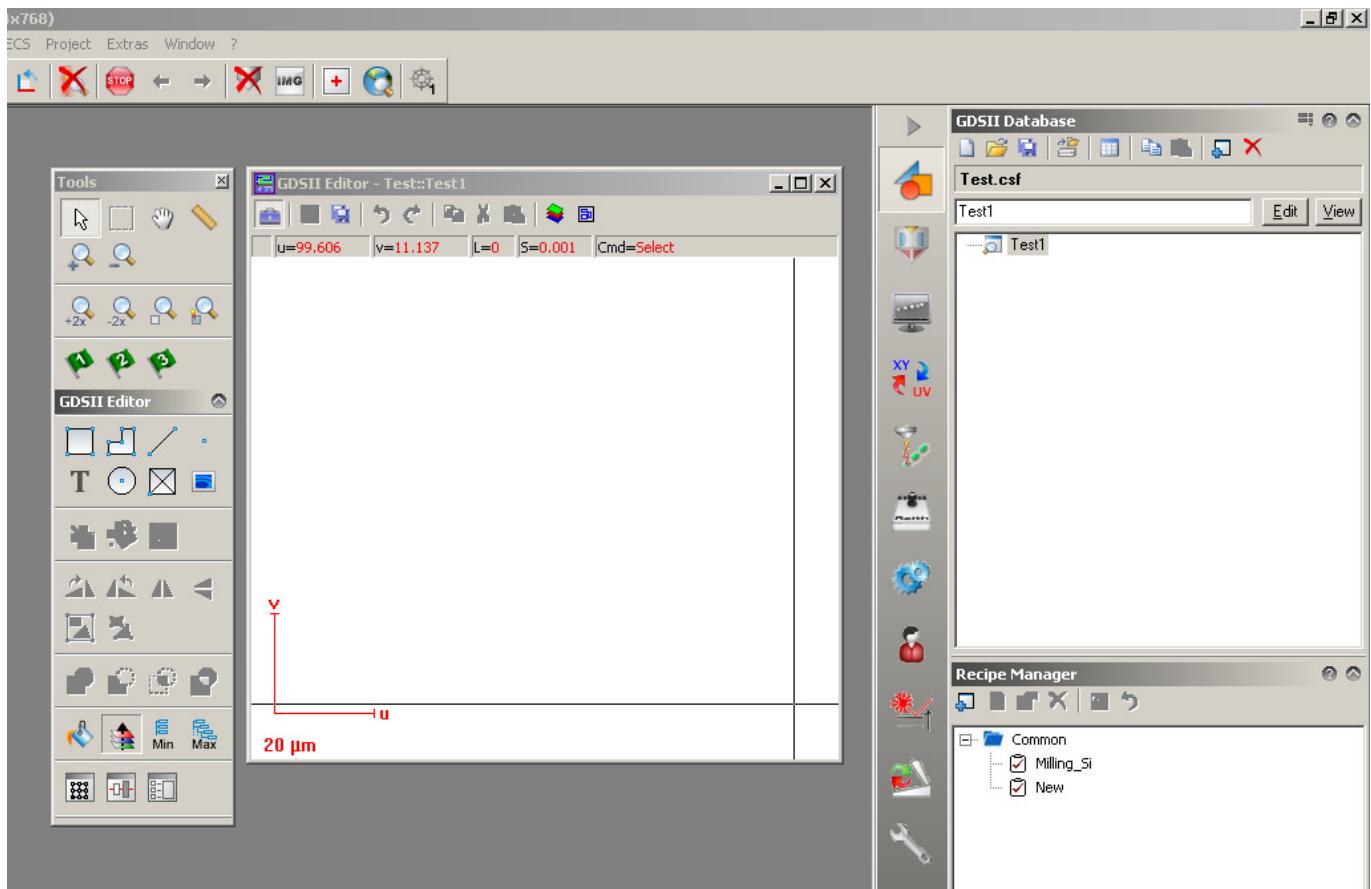
STEP 2

To create a NEW structure in the database, right-click in the blank area and select “New”. Now another dialogue box will open, where you can define the name of the first structure, e.g. “Test1”. After confirming, a new window will open as well as this first structure will appear in the database.

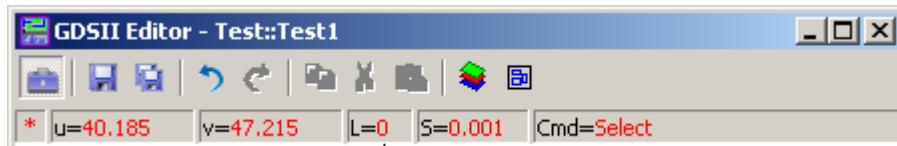


HINT

A design window opened by default because we created a new structure. In general, you can open an existing structure by selecting it and choosing “Edit” for designing and modifying your patterns, or selecting “View” to see the pattern but have no ability to make modifications.



At the top of the Editor window, there are several items of information contained in the status bar:

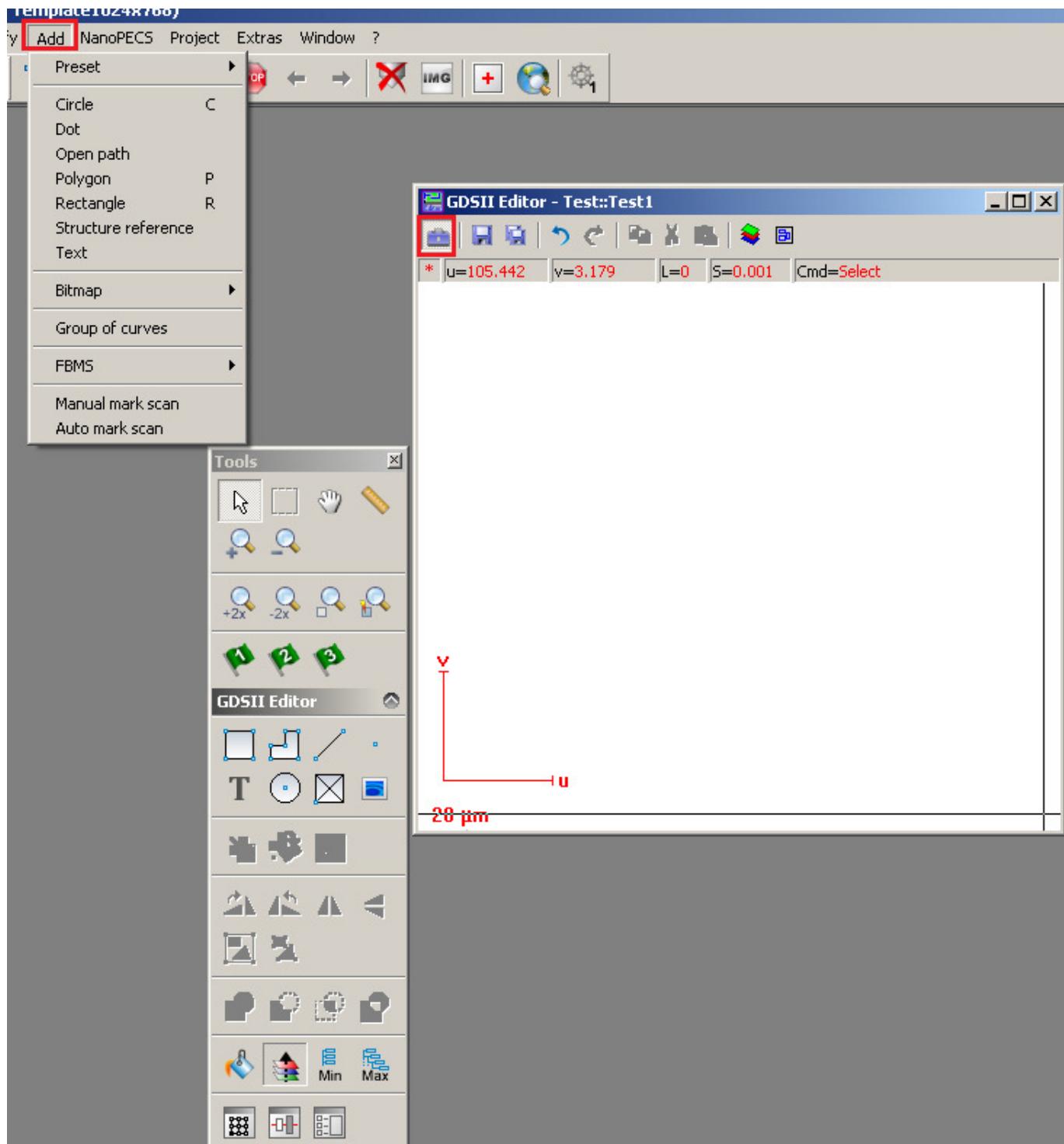


At the top of the Editor window, there are several items of information

- *: A star in the first field highlights unconfirmed changes.
- UV: The actual coordinates of the cursor position in U,V.
- L: The actual layer chosen for design is displayed. The layer can be changed via Add/Preset/Layer.
- S: The selected stepsize of the design grid is displayed. The cursor step size can be changed by either selecting “S” or going to the Options Menu/Design grid. At the moment, the step size is 1 nm, which means that the cursor can only be located at positions with integer microns leading to a corresponding invisible design grid.
- Cmd: The currently used command is displayed. For example, after clicking on Add, the command will show Add.

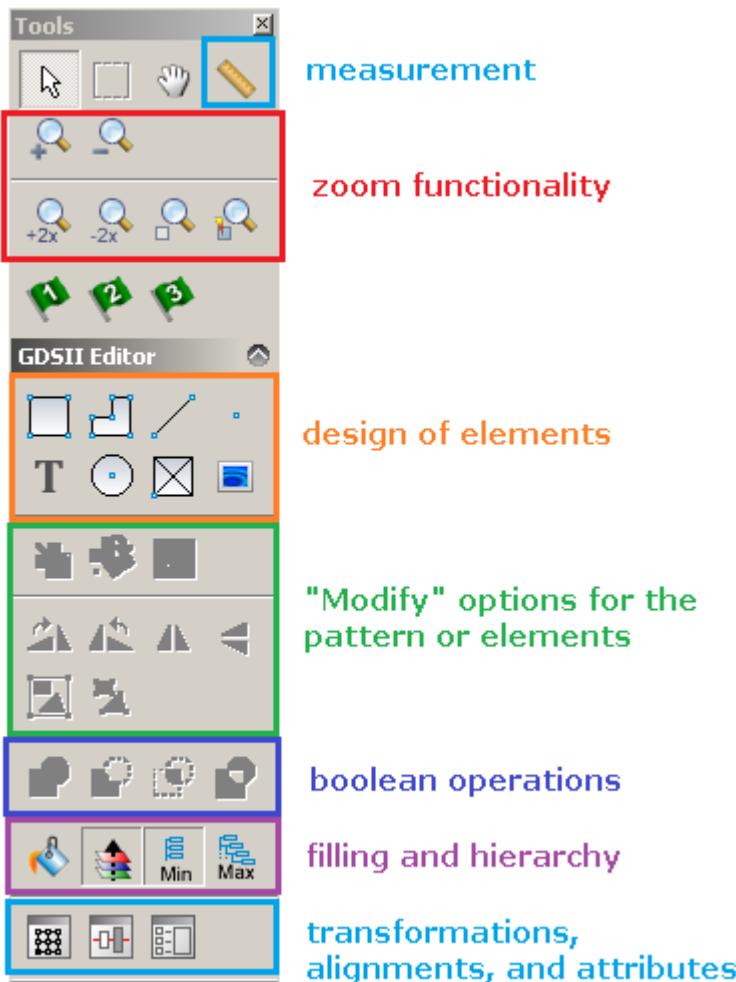
TASK 2: Pattern design via toolbox

STEP 1 If the Toolbox did not open with the editor window, open it via the Toolbox icon in the top left corner of the design window.



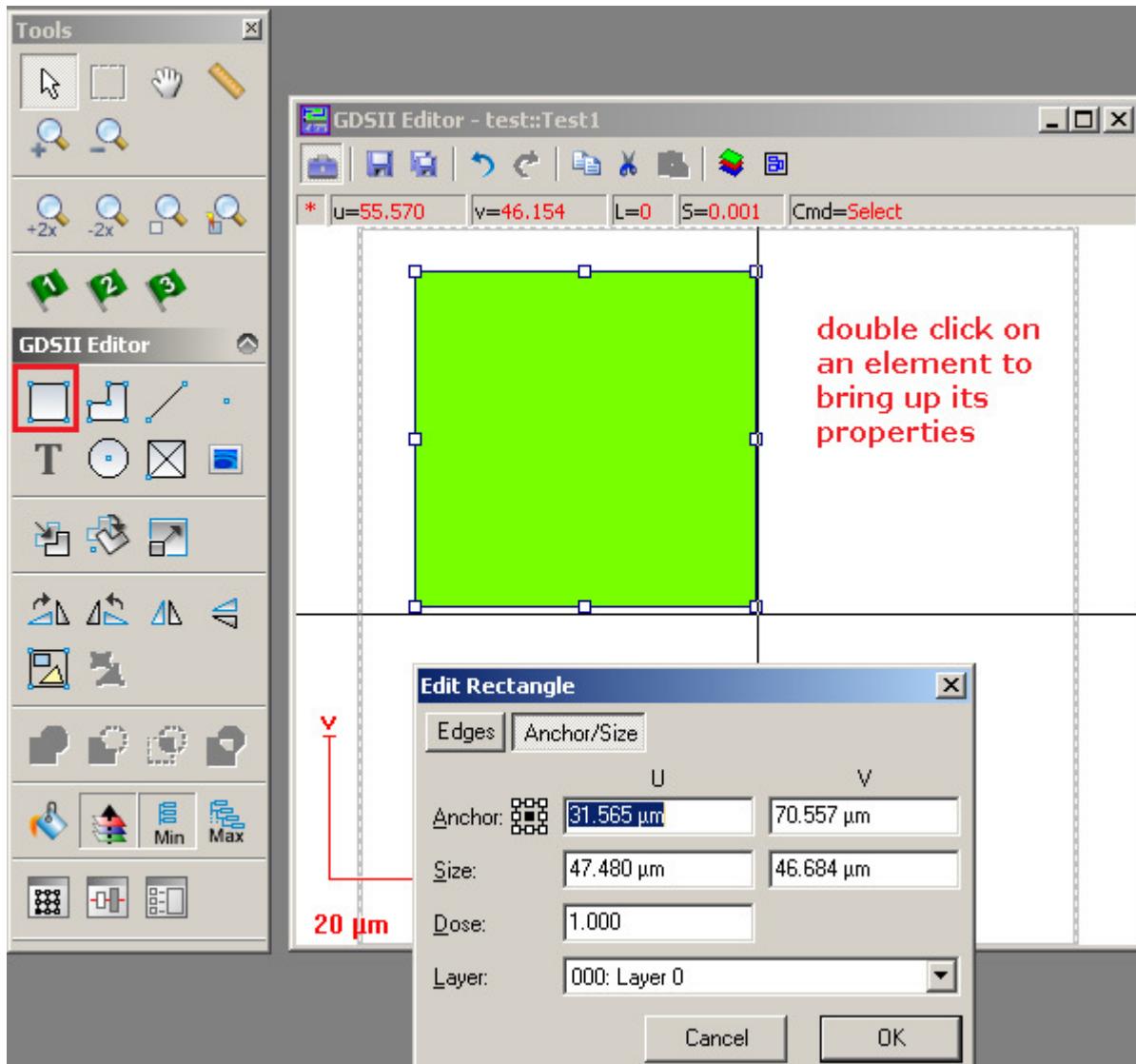
HINT

The icons of the tool box give easy access to the main design functions, which are alternatively accessible via the drop-down list box Modify and Add.



STEP 2

Choose an element to draw. Once done, choose the mouse pointer icon to deactivate the drawing command.

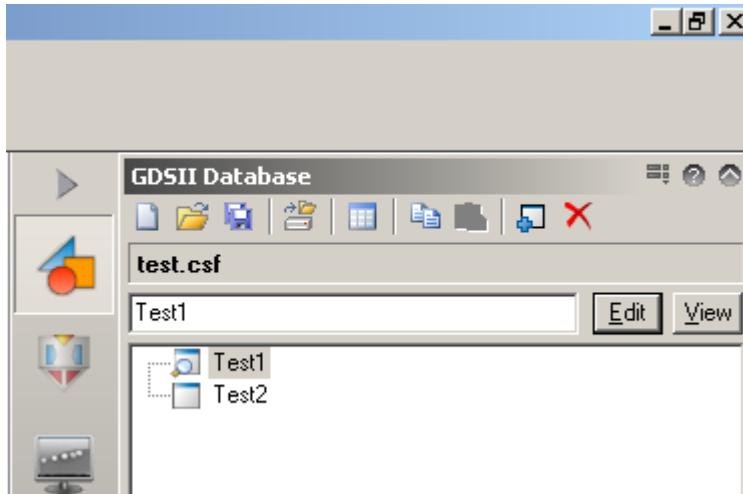


STEP 3 Use the remaining icons to familiarize yourself with their functionality.

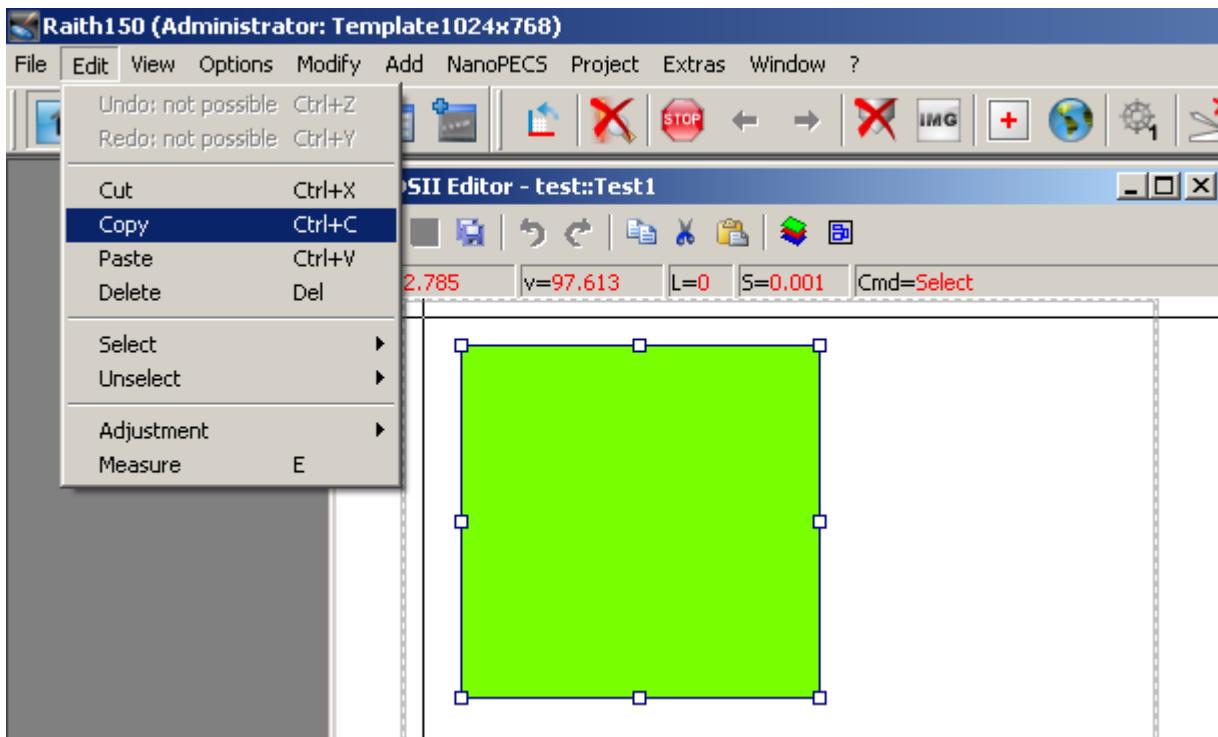
STEP 4 Save the pattern using the “Save” or “Save As” icons in the top left corner of the GDSII editor window.

TASK 3: Multiplying structures

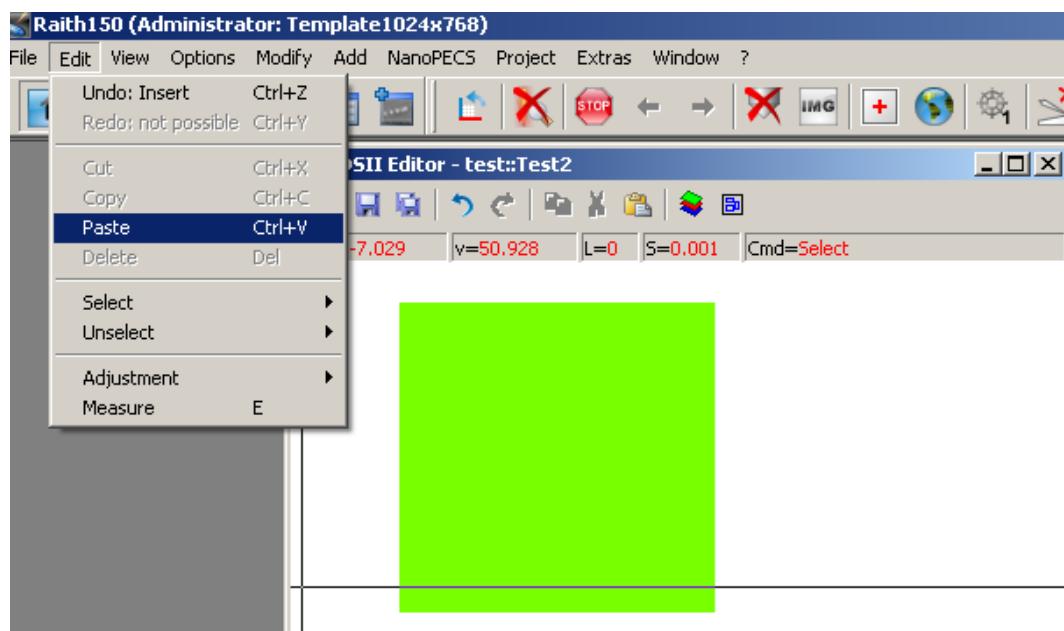
STEP 1 Create new structure in the database, called “Test2”. Do not draw any patterns in the new structure, just save and close the structure.



STEP 2 Open the former pattern “Test1” via the button Edit and click once on the polygon. Once it is selected, the corners are marked by tiny yellow squares.

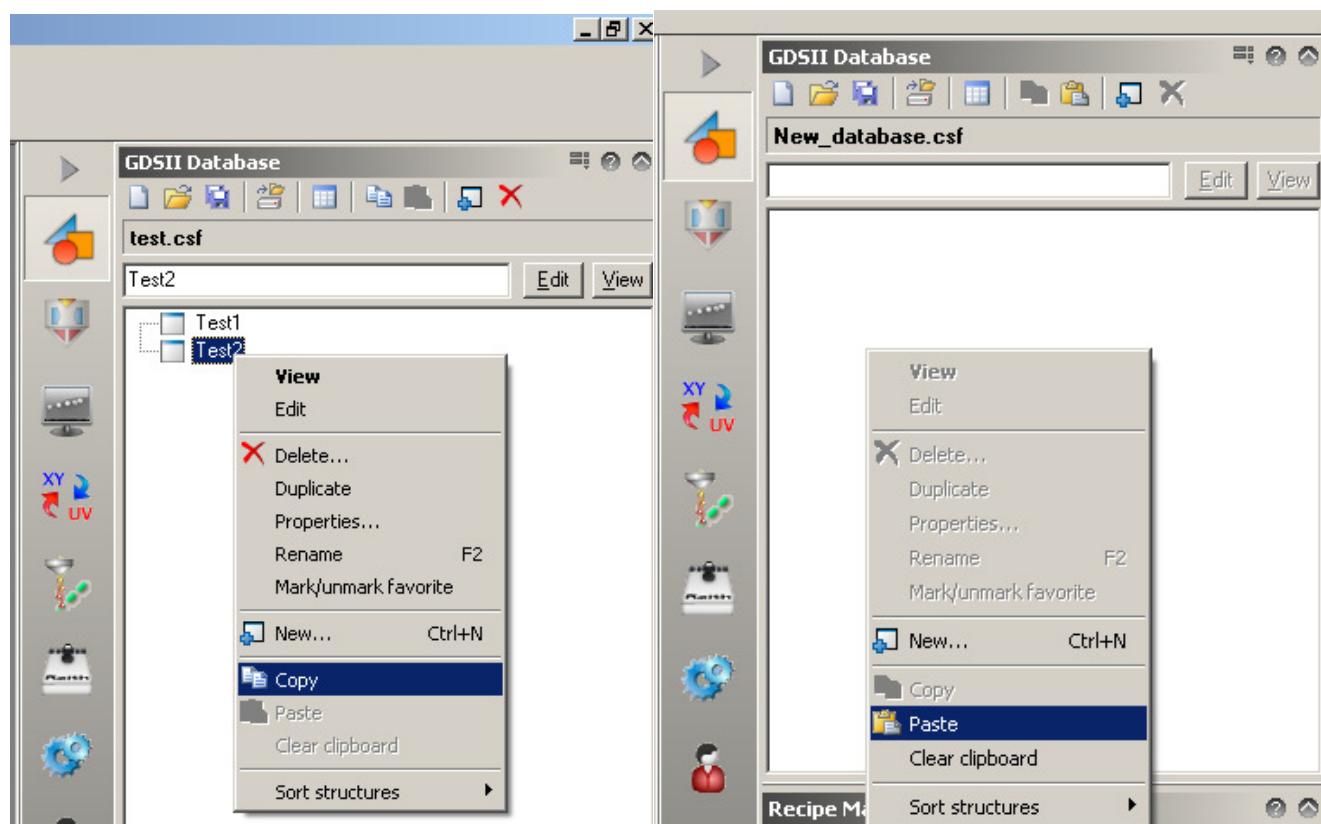


STEP 3 Open the new design “Test2”. Now click Edit/Paste.



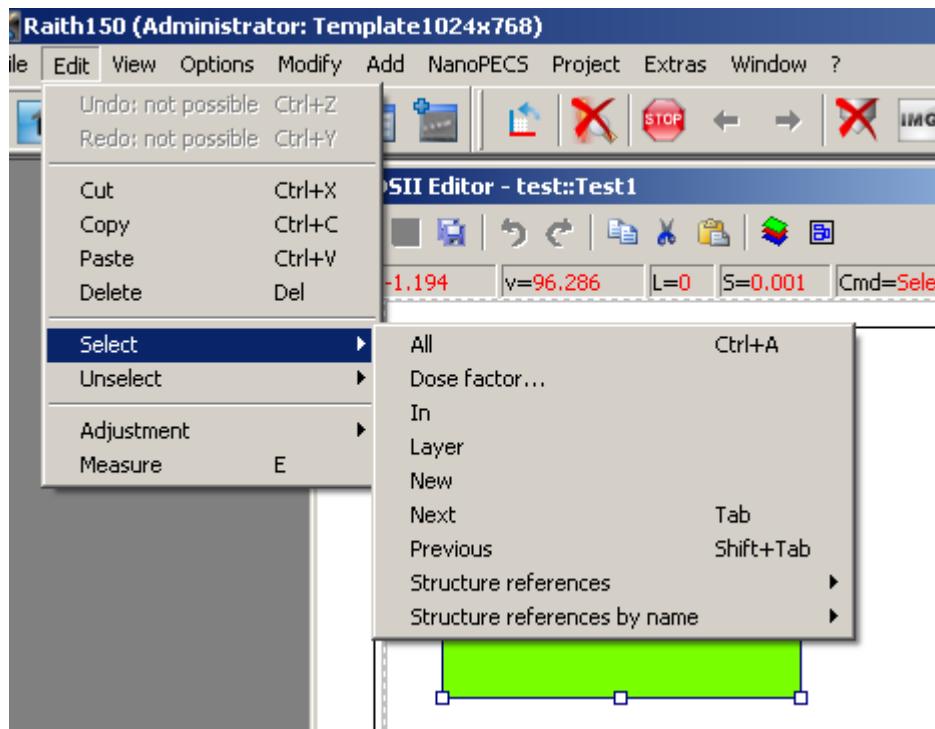
HINT

It is also possible to copy structures between databases, i.e. preventing the user from having to repeatedly draw commonly used structures. Select the desired structure, right-click and select "copy". Now open the new database and right-click and select "paste".

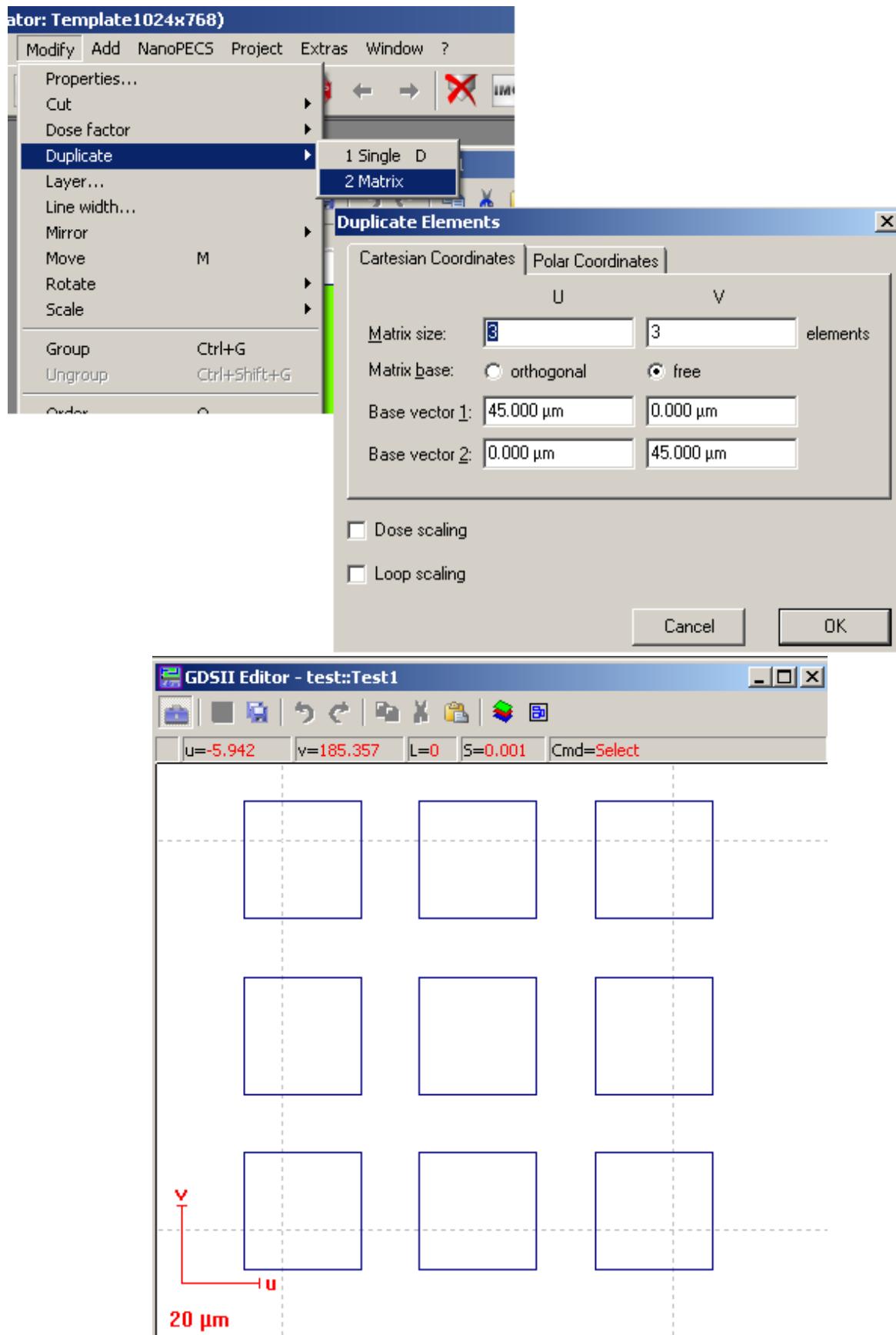


STEP 4 Open the structure "Test1" again. Select the rectangle.

HINT If there are multiple elements to select, you can use the Edit>Select menu option which gives you more choices to select, i.e. by layer, in, dose factor, etc.

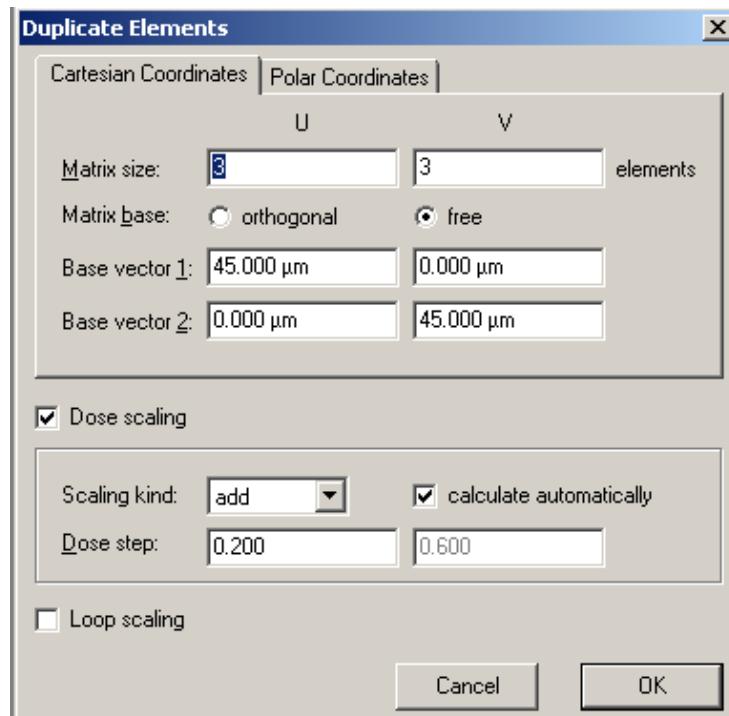


STEP 5 Click on Modify, duplicate and Matrix, which will open the following dialogue box.

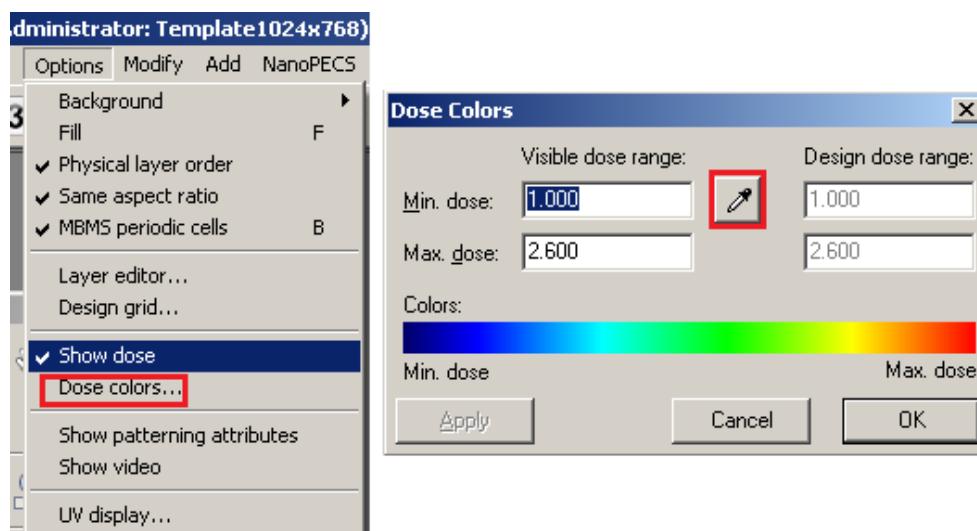


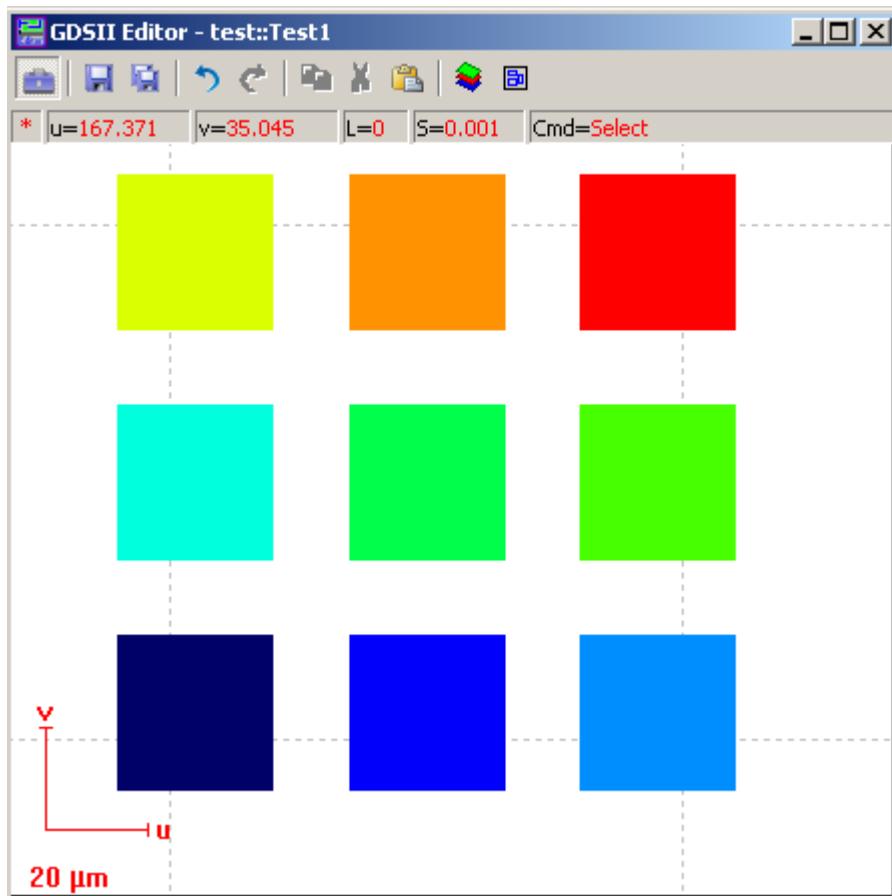
STEP 6 This pattern should be repeated 3 times in each axis. The steps in both axis in this example is 45 μm .

STEP 7 It would also be possible to have the dose of each structure changed to create a dose matrix.



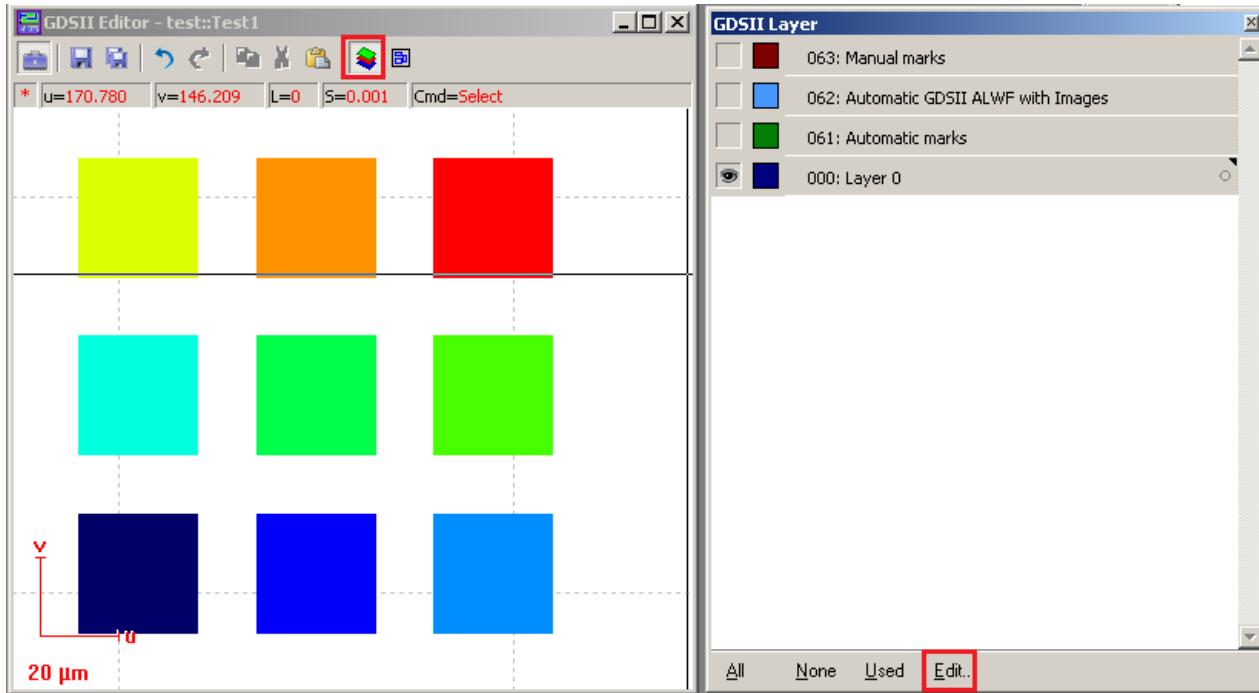
STEP 8 The result is shown in the figure below. To inspect the dose click on Options, Show dose. You will find that all patterns have the same color. To view, change the relationship between dose and color, click on Options, Dose colors and a dialogue window will open. Click on the pipette icon, this will update the visible dose range. Click on Apply to update the GDSII window and confirm with OK.



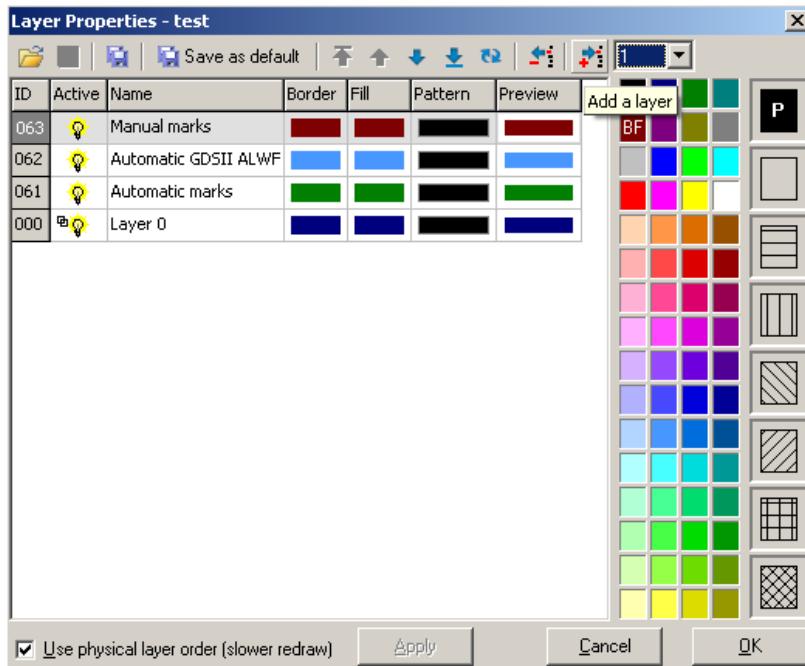


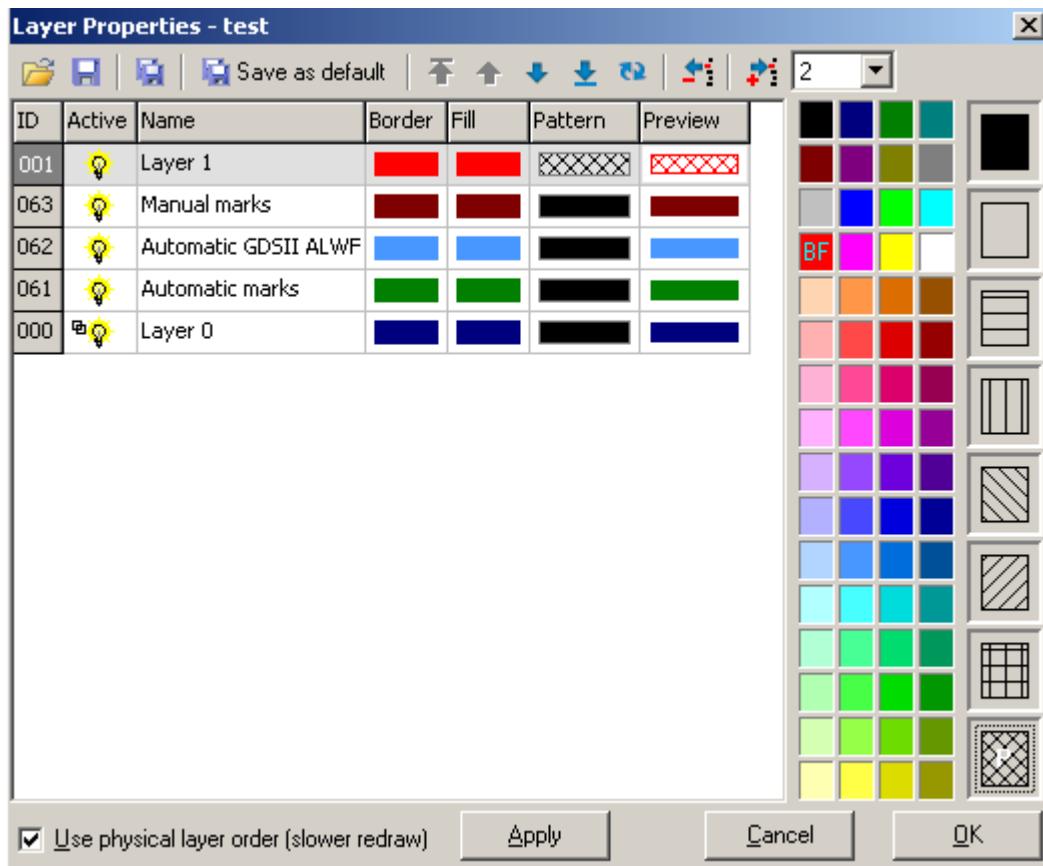
TASK 4: Using different layers

STEP 1 Press the layer icon next to the toolbox. A dialogue window will open, showing the existing layers at this moment. Press Edit and a new dialogue window will open.

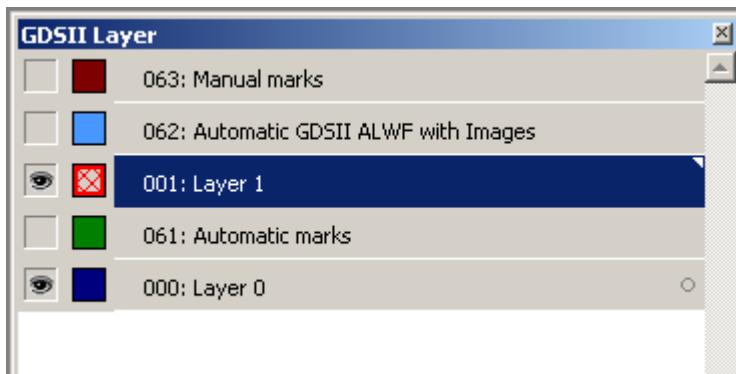


STEP 2 To add a layer, choose the layer number from the drop-down list box on the right hand side and click on Add a layer icon next to it, which will update the table in the Layer Properties window.





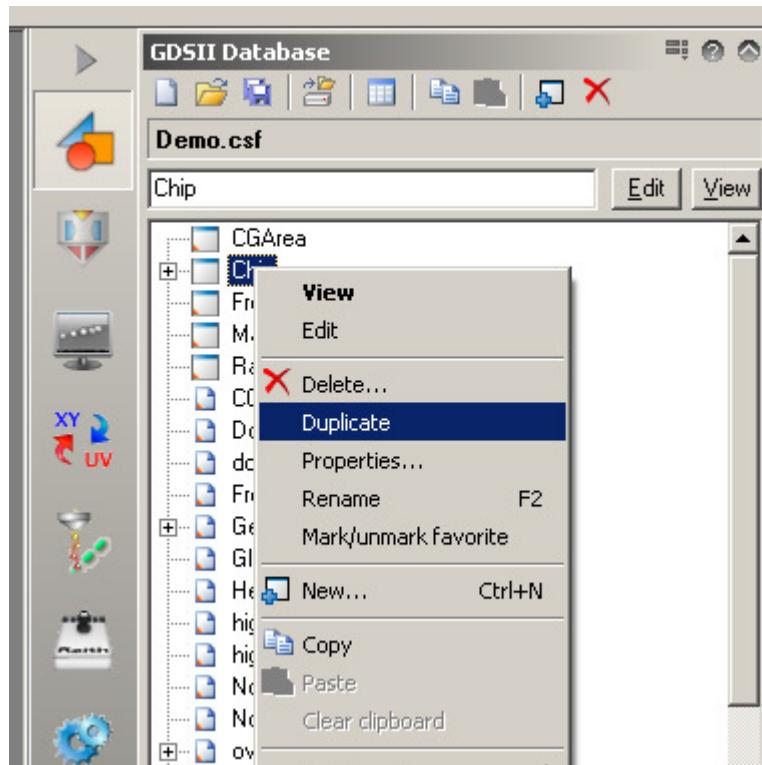
- STEP 3** Enter a name for the new layer, e.g. Layer Demo1. You should now define further properties of this layer. You can change the color of the Border and Fill by moving the mouse to the new color and pressing the left and then right mouse button respectively.
- STEP 4** Press OK and confirm with Yes to save the changes you have made.
- STEP 5** You can make the new layer visible by selecting them in the GDSII layer window and activating the “eye” icon.



- STEP 6** Go to Add, Preset, Layer and select Show all from the dialogue window, select Layer 1 and click OK. The GDSII window will the name in the top of the status bar.

TASK 5: Saving, deleting, and copying of structures/databases

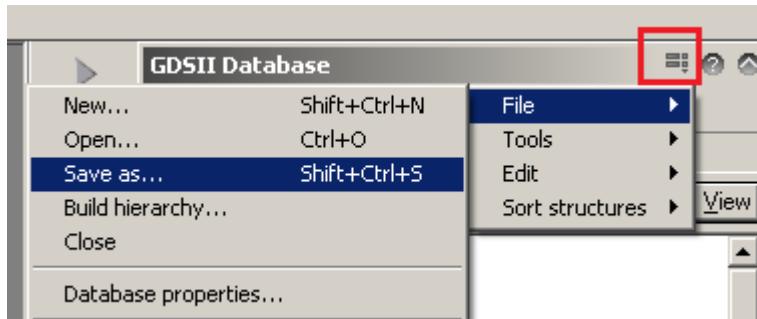
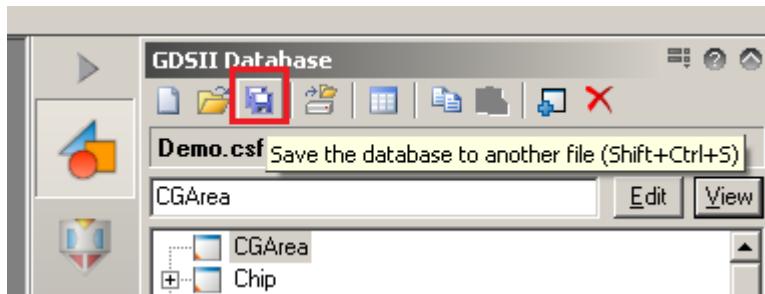
- STEP 1** An existing structure can be deleted by selecting and highlighting that structure(s) and pressing “delete” or selecting the menu option “Edit/Delete”.
- STEP 2** It is possible to duplicate a structure within the same database. Simply highlight the structure, right-click and select “duplicate”.



- STEP 3** It is possible to rename a structure in the database.

HINT The currently opened database is always up to date. If changes have been made to the database, you will be asked to “save” upon closing the editor.

- STEP 4** It is sometimes useful to make a copy of the original database as a backup before applying Database Tools or proximity correction to the Database.



STEP 5 It is useful to copy structures between databases so as not to have to redraw repeating elements, i.e. alignment marks, each time a new database is created. To do so, select the structure and right-click, selecting "copy". Then open the New database, right-click and select "paste"

