adolphe merkle institute
excellence in pure and applied nanoscience

UNIVERSITY
OF FRIBOURG
SWITZERLAND

Focused ion beam

Nanobuilder

Version 1 – September 2024

Universal rules

Rule 1: don't touch a control if you are not sure of the outcome of that action

Rule 2: never, ever force anything beyond finger strength

Rule 3: wear gloves when touching anything that goes into the chamber

Rule 4: if in doubt, ask for help

Nanobuilder environment

NanoBuilder is an application for rapid nano-prototyping using ion-beam processes to create desired structures available in CAD files. Examples of applications are:

- a sloping surface to make a tilted nano-mirror
- optical resonators
- nano-imprinting

The NanoBuilder Product Line consists of NanoBuilder itself and NanoArchitect™ (for use on a PC without a microscope), allowing you to create, view, and edit NanoBuilder jobs. NanoBuilder:

- makes it easy to pattern CAD (GDSII CAD file) designs with the SEM/FIB.
- Optimizes unique parameters for EBID and IBID operation.
- Adds SEM- and FIB-specific information such as beam energy, current, patterning parameters, GIS parameters.
- Automates the alignment of layers/patterns to fiducials on the sample, not only beam shift, but also rotation, magnification and shear errors.
- Automatically patterns the layers/patterns with the given settings at multiple locations on the sample.
- Allows designing structures without the need for an external GDS editor.
- Allows creating structures that span multiple write fields.
- Create structures that span multiple write fields

Other GDS editors include:

Name	**Website**
Layout Editor	http://www.layouteditor.net/
KLayout	http://www.klayout.de
CleWin	http://www.wieweb.com
L-Edit Pro	http://www.tannereda.com/l-edit-pro
Electric	http://www.staticfreesoft.com

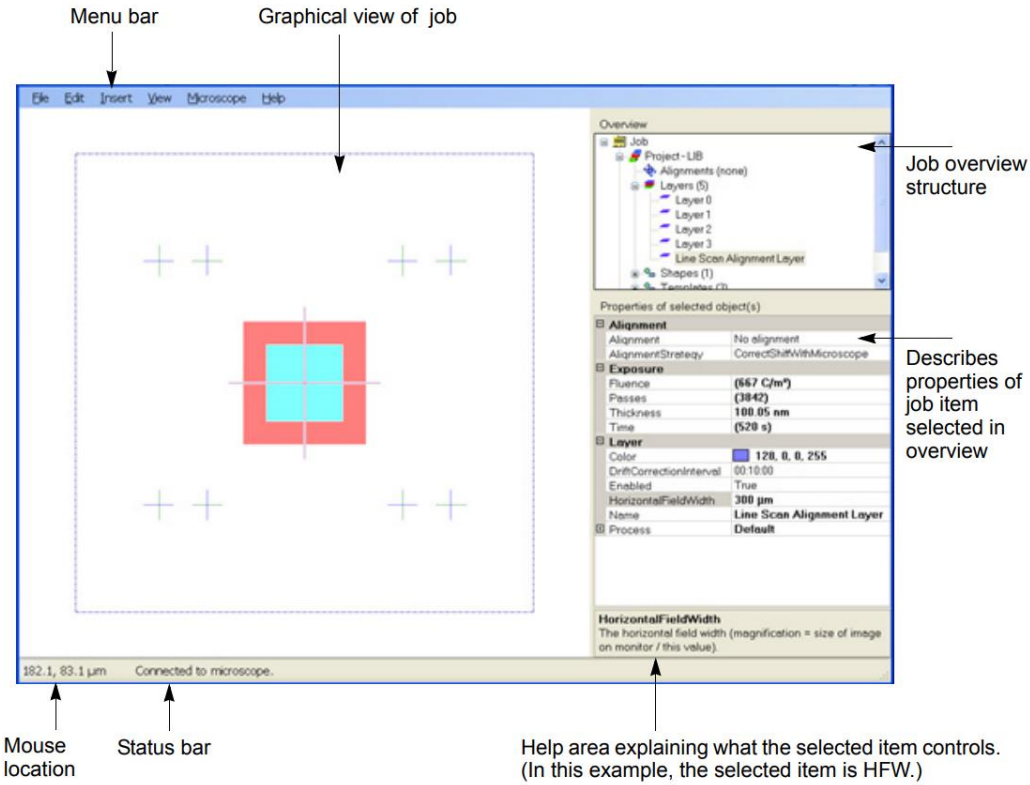
Demonstration: Nanobuilder User interface

Prerequisites:

Sample loaded, stage pumped

E-beam and ion beam active

Learn about the graphical user interface



Demonstration: Shapes

Prerequisites:

Sample loaded, stage pumped

E-beam and ion beam active

Learn about the three different shape types in Nanobuilder

The shapes in NanoBuilder are grouped in a number of categories:

- **Basic shapes**: Simple geometric shapes
- **Composite shapes**: Shapes that are combinations of other shapes
- **Special shapes**: Shapes that deviate from the general concept of a shape

- Shape Properties

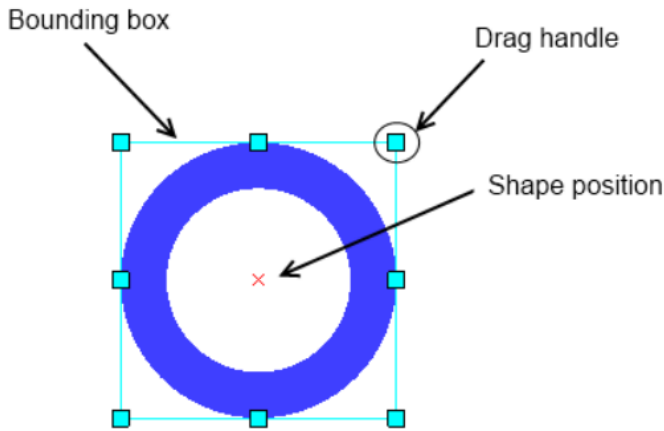
Each shape has a number of properties that are shown in the property box when the shape is selected.

- Some properties are applicable to all shapes (Name, Position, Layer), while others will vary from shape to shape.
- The available ScanDirections, (in the order which the pattern points are generated/rastered), will also depend on the specific shape.

- Display and Selection

Shapes are visualized with the color of their layer and drawn in the same order as they are listed in the project. A slight transparency is applied to ensure overlapped shapes are still visible.

A shape is selected by clicking on the shape in the viewer or by clicking on its node in the overview tree. When a shape is selected, additional annotation is shown: its position (red cross), the bounding box, and drag handles.


Bounding box
Drag handle
Shape position

Demonstration: Shape editing

Prerequisites:

Sample loaded, stage pumped

E-beam and ion beam active

Create new shapes in Nanobuilder

When a shape is selected, its size and position is editable directly in the viewer. Adjust the size by using the drag handles that are attached to the bounding box of the shape.

To move the shape, position the mouse cursor inside the bounding box and drag the shape (hold the mouse button down while moving).

For ultimate precision, use the property box (lower-right part of the screen) to edit the position and dimensions (and other properties of the shape) using numeric keyboard input.

Adjust the order in which the shapes are patterned (and displayed) by dragging their nodes in the overview tree. Alternatively, right-click on the shape in the overview tree and use the menu items Move Up, Move Down, Move to Top, and/or Move to Bottom to adjust the order.

- Grid and Snap

A grid with snapping drag handles is available to facilitate shape editing in the viewer. The grid can be enabled via View > Grid.

The grid will scale dynamically with the zoom level with no need to specify the grid-spacing. If you need a higher grid density, just zoom in.

- Basic Shapes

The basic shapes are the straight-forward geometrical shapes and can be considered as the NanoBuilder primitives.

Circle

The circle represents a solid disk. If the inner radius has a value greater than 0, it becomes a donut.

Shape-Specific Properties:
- Outer radius
- Inner radius

Circle shape

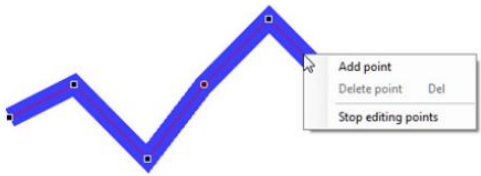
Circle shape with inner radius > 0

Path

A path is a single line or a number of connected lines, all with the same line width. To edit the points (or add/delete points), select the path shape, right-mouse click and select Edit Points. The shape will now be shown in Edit Mode, allowing you to drag the points. Add points by dragging the red line between two points; this will insert a new point between the two points. Alternatively, enter the exact point coordinates in the shapes property area.

Shape-Specific Properties ν EndStyle: Specifies how the two ends are drawn (rounded or straight) ν Width: The line width of the path ν Points: The end points of the line segments that define the path

Path shape



Path shape in edit mode

Shape-Specific Properties:
- EndStyle: Specifies how the two ends are drawn (rounded or straight)
- Width: The line width of the path
- Points: The end points of the line segments that define the path

Rectangle

The rectangle represents a solid rectangular area, specified by its width and height.

Shape-Specific Properties:
- Width: Horizontal dimensions
- Height: Vertical dimensions

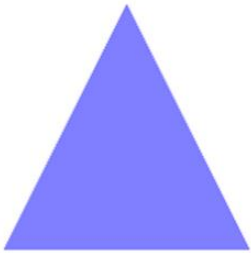
Polygon

A polygon is a solid multi-line shape, varying from three-point triangle to any number of points. To edit the points (or add/delete point), select the polygon, right-mouse click, and select Edit Points. The shape is now shown in Edit Mode, with points that drag.

Points can be added by dragging the red line between two points. This will insert a new point between the two points. Alternatively, enter the exact point coordinates in the shapes property area.

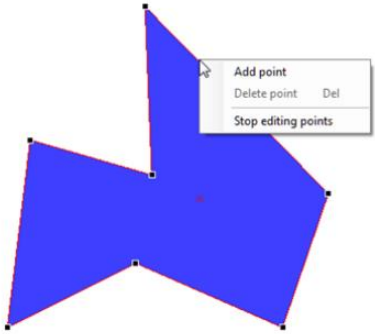
Shape-Specific Properties

The points are the end points of the line segments that circumference the polygon.



Triangle: a 3-point polygon

A polygon with 7 points



A polygon in edit mode

Text

With the text shape the design can be annotated with text labels; these labels are patterned and behave just like any other shape.

Shape-Specific Properties

- Alignment: Specifies how the text is placed with respect to the position
- Font: Specifies font type, style, and size
- Text: the text to display and pattern

- Composite Shapes

Composite shapes are shapes that are a combination of other shapes. The specific composite shape defines how the shapes are combined.

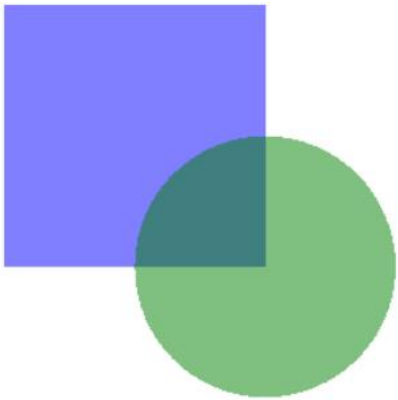
Boolean Shapes and Reference Shapes can be identified within the composite shapes.

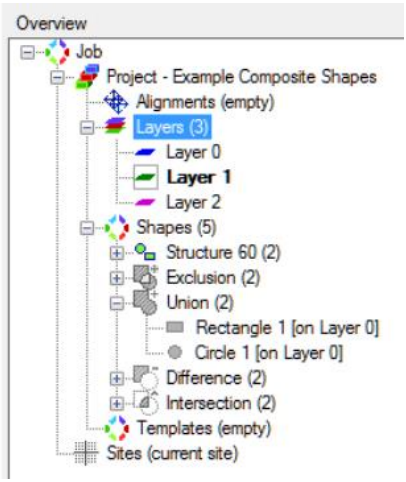
- Boolean shapes use logical operations like AND, OR, XOR to combine the child shapes. The child shapes can be composed by dragging the shapes into the composite within the tree view. Though Boolean operations are typically applied to two operands, in NanoBuilder any number of child shapes is allowed. The individual shapes that make up the composite can be edited independently. With Boolean Shapes, all child shapes will inherit the layer of the composite.
- Reference shapes implement the concept of re-using copies of an existing shape (the template). Such references are based on a transformation or repetition of one of the shapes that has been placed in the Templates collection (see “Reference”).

Composites can be nested allowing you to create complex shapes.

Structure

A structure is a collection of shapes, typically used for grouping shapes in a functional block. The individual shapes can reside on different layers.



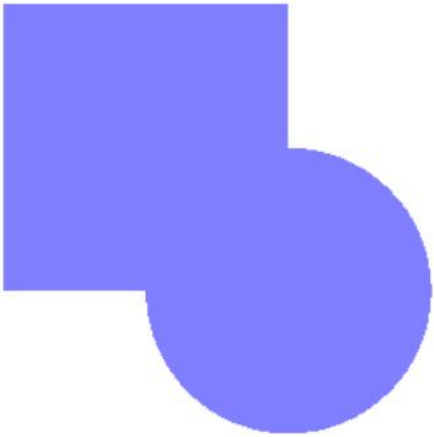


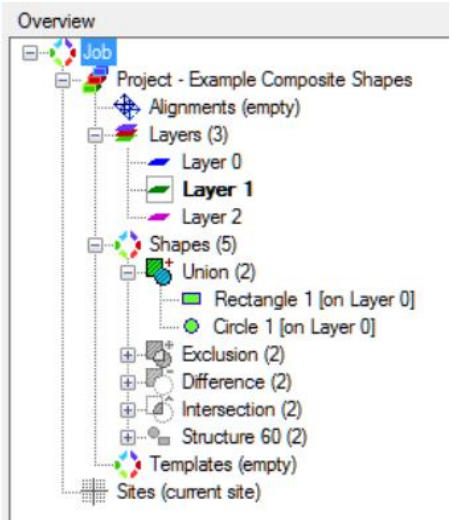
Shape-Specific Properties

If Always pattern parallel is selected, the shapes within the structure are patterned in a parallel fashion, even if the layer is set to serial pattering.

Union

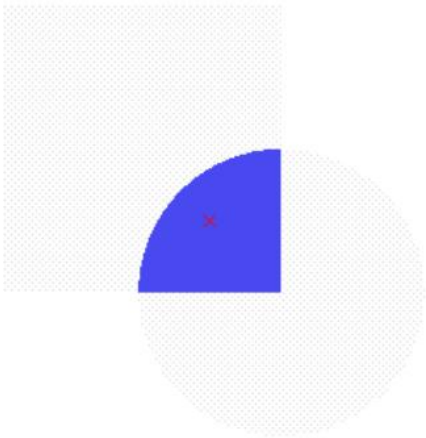
The union shape is the equivalent of the Boolean OR operation, merging the constituents into one big shape. Unlike the Structure, overlapping parts are not patterned twice.

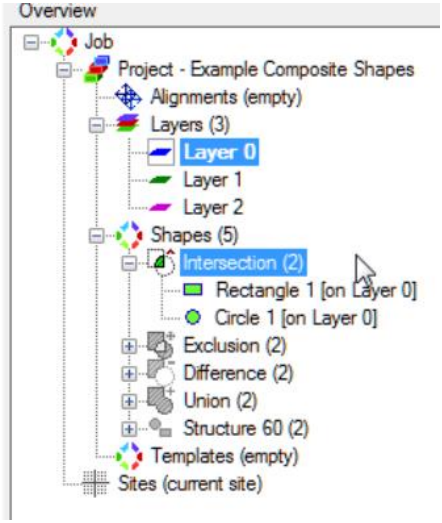




Intersection

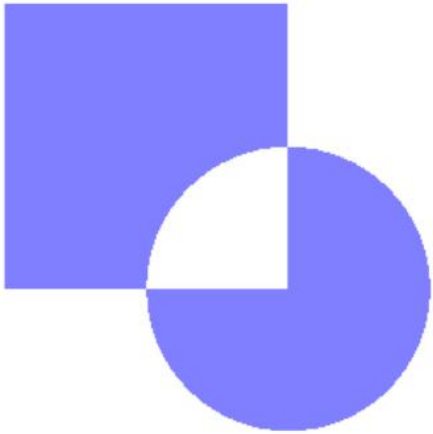
The intersection shape is the equivalent of the Boolean AND operation, only patterning the overlapping parts of the shapes.

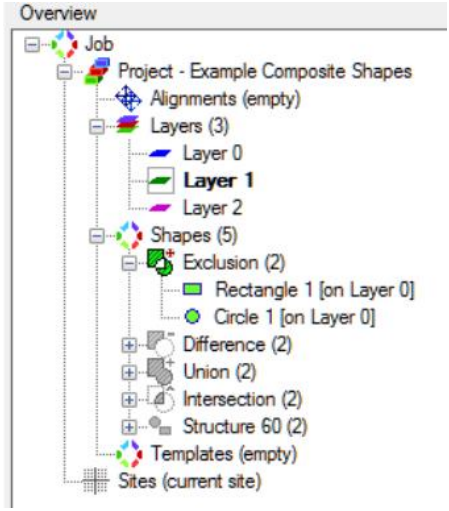




Exclusion

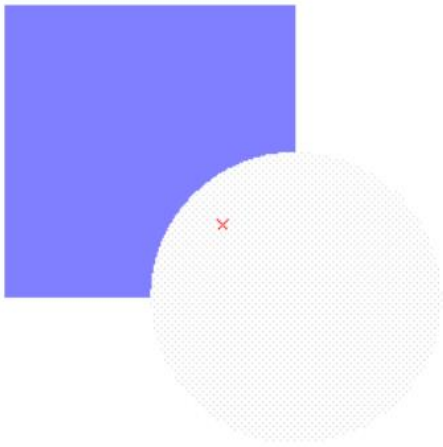
The exclusion shape is the equivalent of the Boolean XOR operation, patterning everything except for the overlapping parts of the shapes. This is the inverse of the Intersection shape.

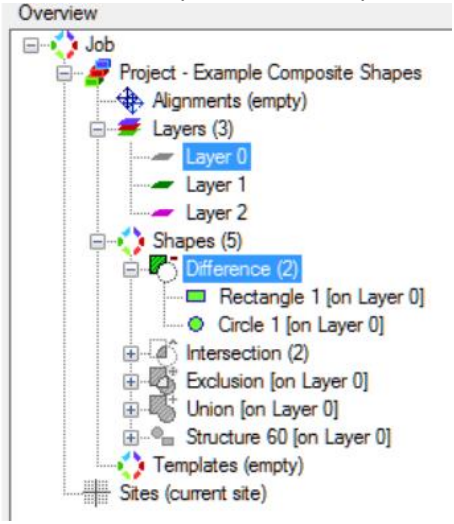




Difference

The Difference shape is the equivalent of subtraction operation, removing the parts from the first shape that are overlapped by the other shapes. The difference shape can be used to invert part of a design: use a rectangle as the first shape to define the 'exclusion zone' (which is milled away), in which the other shapes will not be patterned.



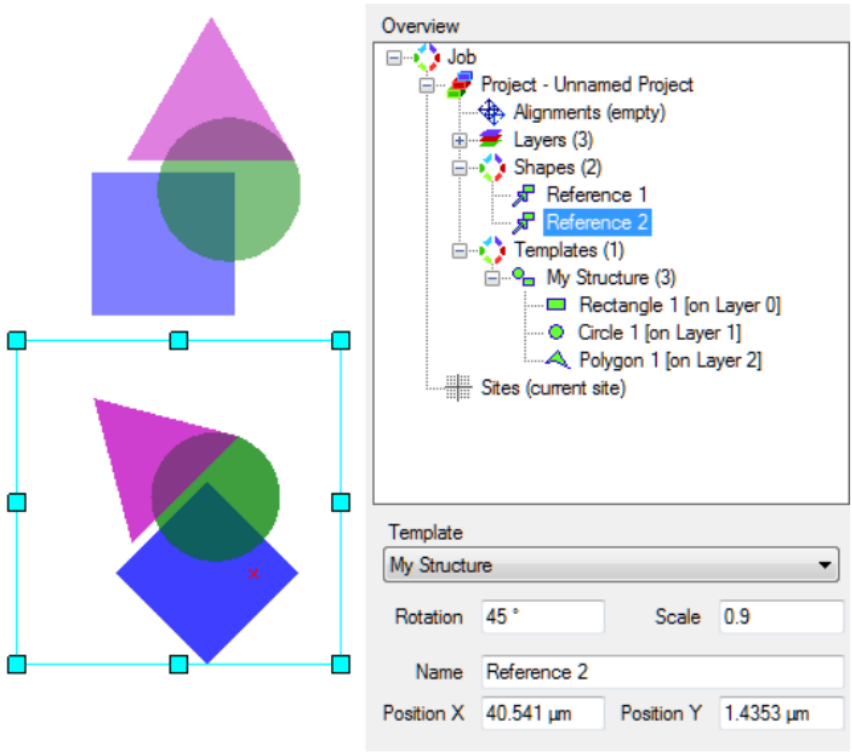


Reference

The Reference shape holds the concept of re-using an existing shape (the template) at different locations and optionally adjusting its size and/or rotation. In order to re-use another shape, that shape first has to be promoted to a template, which is accomplished by dragging the shape to the templates node in the tree view. The image below shows two instances of a reference shape; with and without a rotational offset. In this example the referenced shape is a structure.

Shape-Specific Properties

- Template: The shape that is used as the template for this shape
- Rotation: Angle to rotate the template with (default is 0)
- Scale: Scale factor to increase or decrease the size of the template (default is 1)



Array

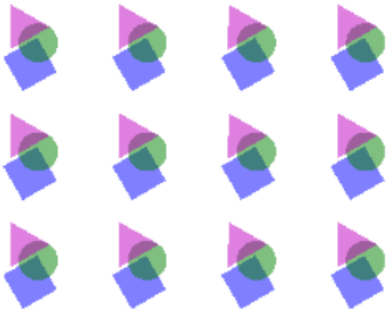
The Array shape allows you to repeat in existing shape in a regular grid. Optionally the repeated shape–which has to be a template–can be rotated and rescaled when it is repeated in the grid

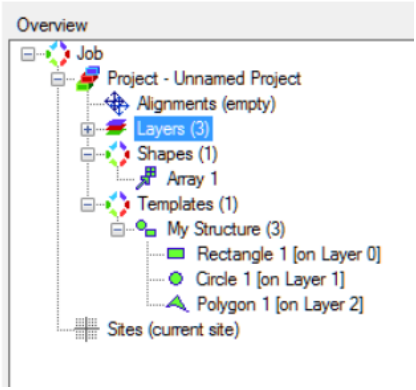
Shape-Specific Properties

- Template: The shape that should be repeated in the array (the referenced template)
- Rotation: Angle to rotate the template with (default is 0)
- Scale: Scale factor to increase or decrease the size of the template (default is 1)
- Columns, rows: The number of columns and rows for repeating the template
- Pitch X,Y: The spacing between the repeated shapes
- Center X,Y: This is an alternative representation of the position of the array, using the center as the point of reference; this facilities aligning the center of the array to a specific position

- Always pattern parallel: If selected, the shapes within the array are patterned in a parallel fashion, even if the layer is set to serial patterning

The following image is a shape array using a 3 x 4 grid and a rotational offset. In this example the repeated shape is a structure:





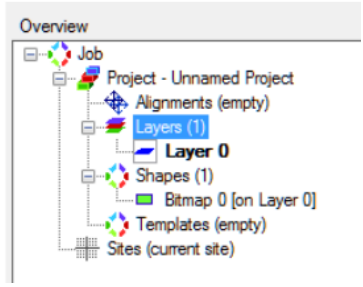
- Special Shapes

The special shapes are shapes that deviate from the general concept of shapes, for example in how they are rastered or how process parameters are applied.

Bitmap Shape
The bitmap shape is a pattern that uses an image from disk as the basis for patterning. The different gray scale values of the pixels are translated to specific dwell times at the corresponding pixel locations, such that after patterning an imprint of the image remains. The result of the Bitmap Shape is equivalent to patterning a bitmap in the xT UI.

Shape-Specific Properties
- Bitmap: The image used for the shape; to change files, click the [...] button in the field. A bitmap shape is always patterned in a row-by-row serpentine, starting at top-left corner.
- Physical height and width: The actual dimensions of the image when it is patterned

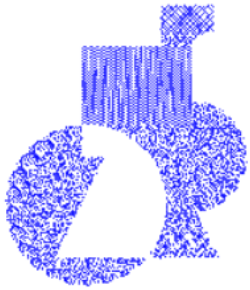
- Pixel: The size of a pixel when patterned (pixel size = physical size/bitmap resolution). The maximum possible dwell time of a pixel–if it has value 255–is the dwell time as set for the layer.

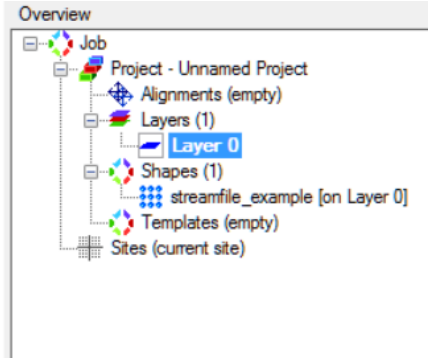


StreamFile Shape

The StreamFile shape allows you to add an existing stream file (a native xT format for specifying pattern points) to be included in the design. The stream file has to be specified when the shape is added.

- The dwell times of the points in the stream file are not determined by its layer, but merely by the times specified for each point in the stream file.
- The number of passes is determined by the layer. When loading a stream file the number of passes for the layer is initially set to the value from the stream file, but you can edit this afterwards.
- Because the number of points in a stream file can be considerable, not all points are drawn for performance reasons. They may lead to interference patterns in the display. Zooming in to scale of a pattern point will show all points within the view port.





Demonstration: Job editing

Prerequisites:

Sample loaded, stage pumped

E-beam and ion beam active

NanoBuilder allows creating designs through shapes. Note shapes are supported that are not available in GDS, such as circles, Boolean shapes, bitmaps, and stream files.

Note: NanoBuilder currently cannot save in the GDSII format, and the format of its native .nbj files may change in the future.

Therefore, for long-term design use, it is better to make a GDSII file and convert that to NanoBuilder

- Creating a Job

Start NanoBuilder.
Go to File > New Job to create a new job.

- Creating a Layer

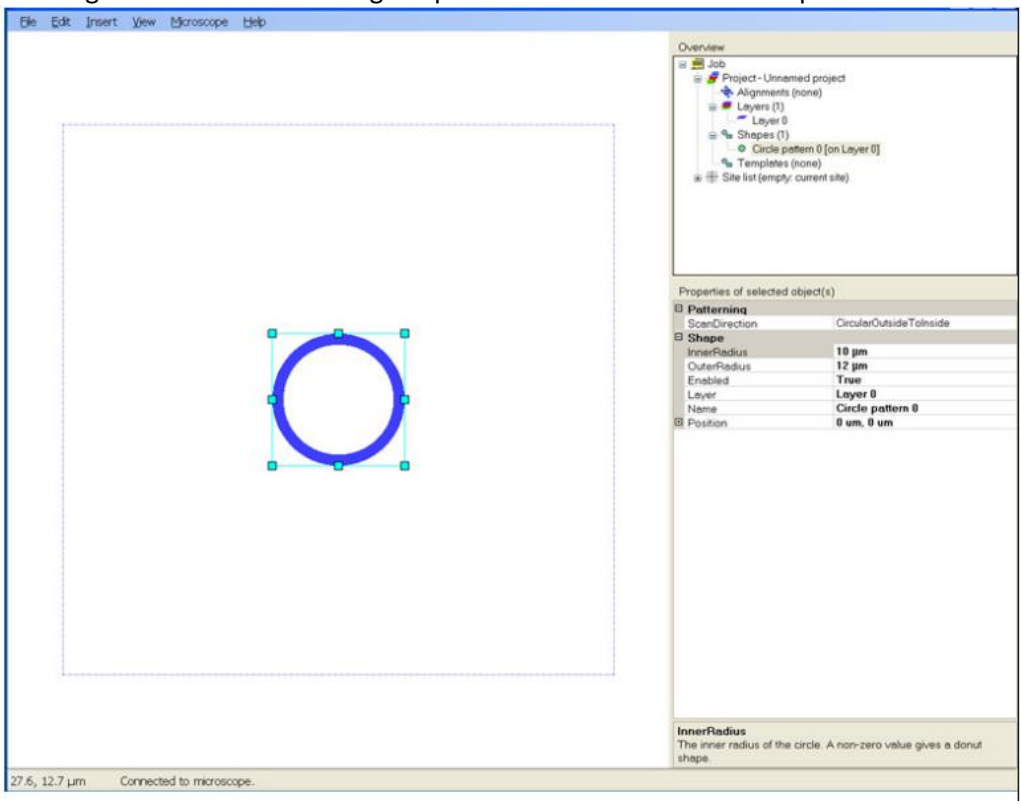
1. Go to Insert > Layer to add a layer.
2. Change the HorizontalFieldWidth and Thickness properties to the appropriate value for the size of the job.

- Creating a Circle

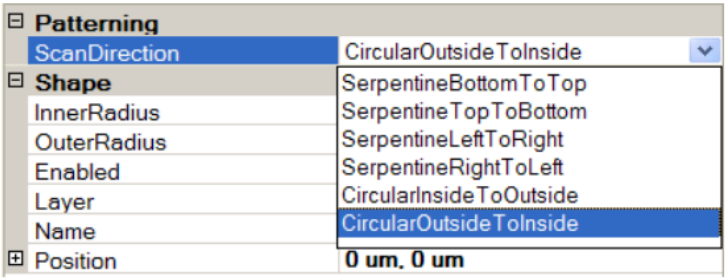
1. Go to Insert > Basic Shapes > Circle[1].

[1] New shapes are placed in the screen center and are sized to about 10% of the screen width.

2. Click on the circle that appears to select it. Resize the circle using the drag handles or enter the exact radius numerically.
3. Change the inner radius to e.g. 10 µm and the outer radius to 12 µm.

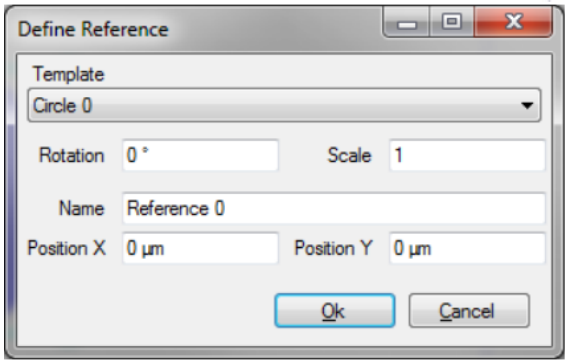


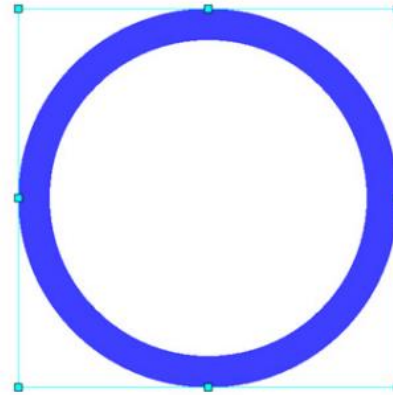
4. Select the scan direction for patterning. (See also “Scan Direction” below)



- Creating a Reference

1. Create a circle.
2. Drag the circle from Shapes to Templates (in the tree view).
3. Go to Insert > Composite Shapes > Shape Reference.





This allows you to select a template shape (for reference), the rotation and scale, and the position (offset with respect to the template's position).

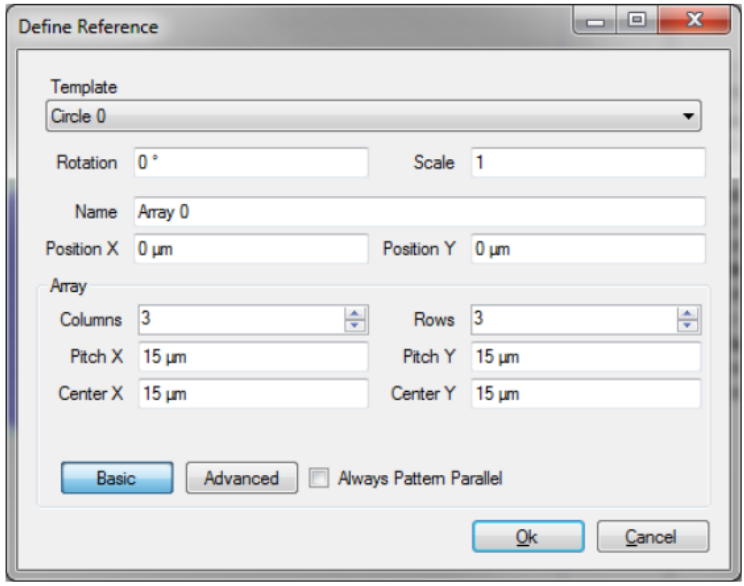
4. Under Template, select the circle pattern you just created.
5. Change the scale to 3.
6. Click OK. Your job now looks something like above.

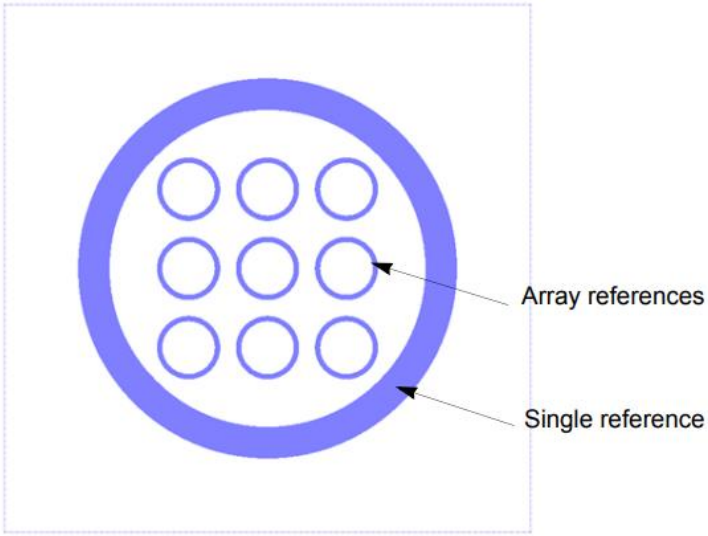
- Creating an Array

An array is similar to a reference, but it allows you to make multiple copies at once. (Assuming the circle has been moved to the Templates section as described above)

1. go to Insert > Reference > Array. The Define Array dialog box displays.

2. Select the circle pattern you created as the template.
3. Change the scale to 0.5 to reduce the size of the ring.
4. Change the number of columns and rows to 3
5. Change the width to 30 µm and the height to 3 µm.
6. Click OK. The result should be similar to that shown below.





Changing array properties

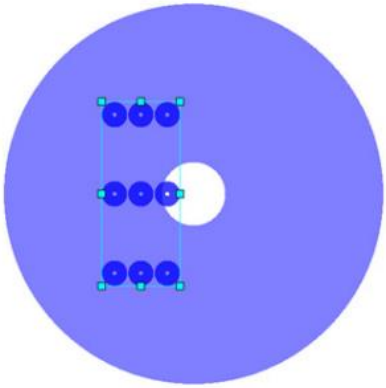
1. Select Array 0 in the Shapes list in the Overview pane.
2. Change the Magnification to 0.2, and set the column pitch to 5 µm

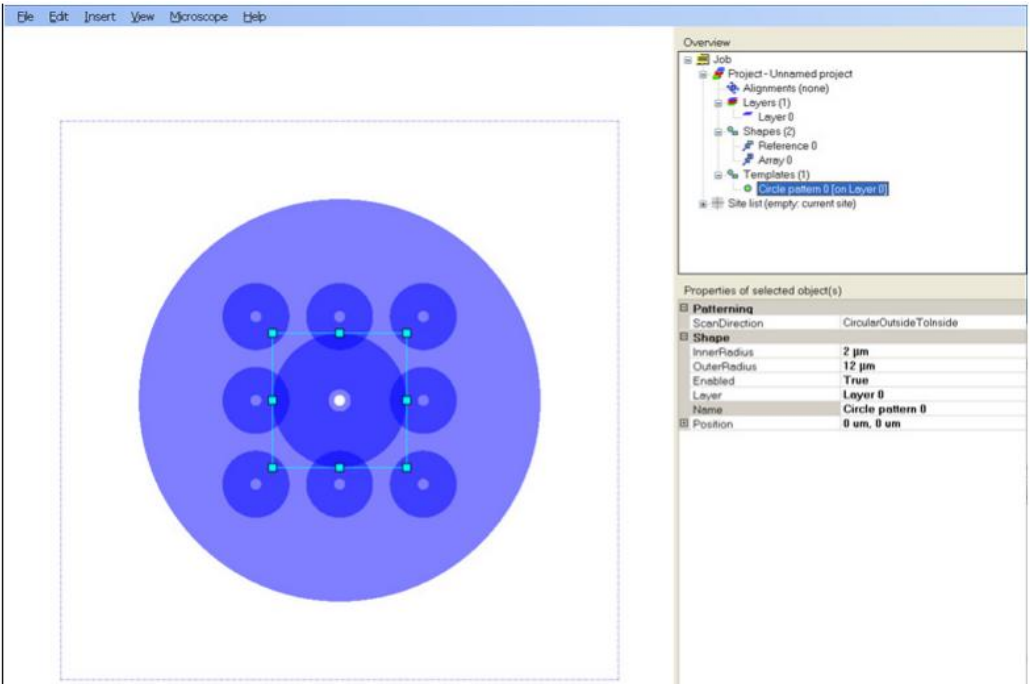
Reference Shape Influences Design

To see how changing the reference shape influences the design:

1. Select the circle template.
2. Change the inner radius to 2 µm (from 10 µm before).

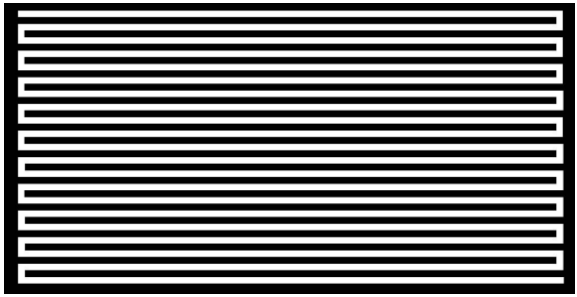
As shown below, both references have changed. When you change a template, all references to that template will change. Also note that the original circle displays when it is selected in the Overview pane.





- Scan direction

NanoBuilder defines six different scan directions:
- Serpentine bottom to top
- Serpentine top to bottom
- Serpentine left to right
- Serpentine right to left
- Circular inside to outside
- Circular outside to inside



Tutorial: Creating and executing a job with alignment from file

Prerequisites:

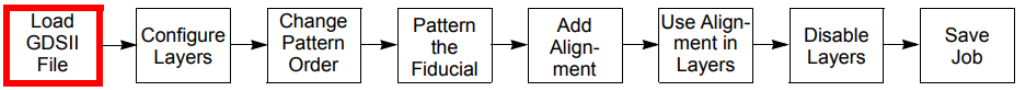
Sample loaded, stage pumped

E-beam and ion beam active

Load a file, specify the patterning, add alignments and execute the job

Note: Nanobuilder does not adjust focus and stigmation! Therefore, all the beam currents being used must be in focus and stigmated. Small amounts (< 2 µm) of beam shift between the currents are allowed.

- Step 1: Import a GDSII file



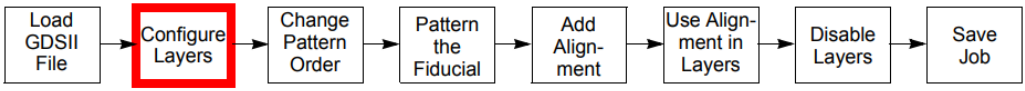
Although you can create designs in NanoBuilder, this tutorial starts from a GDSII file, as this is a common use case. You create your design offline.

Experiment: load a GDSII file

- File > Import GDSII > go to: c:\Program Files (x86)\Fei\NanoBuilder\ - Documentation\Tutorials\Tutorial01
- Open the file Tutorial01.gds

Note: **do NOT overwrite the file**! Save is under another name.

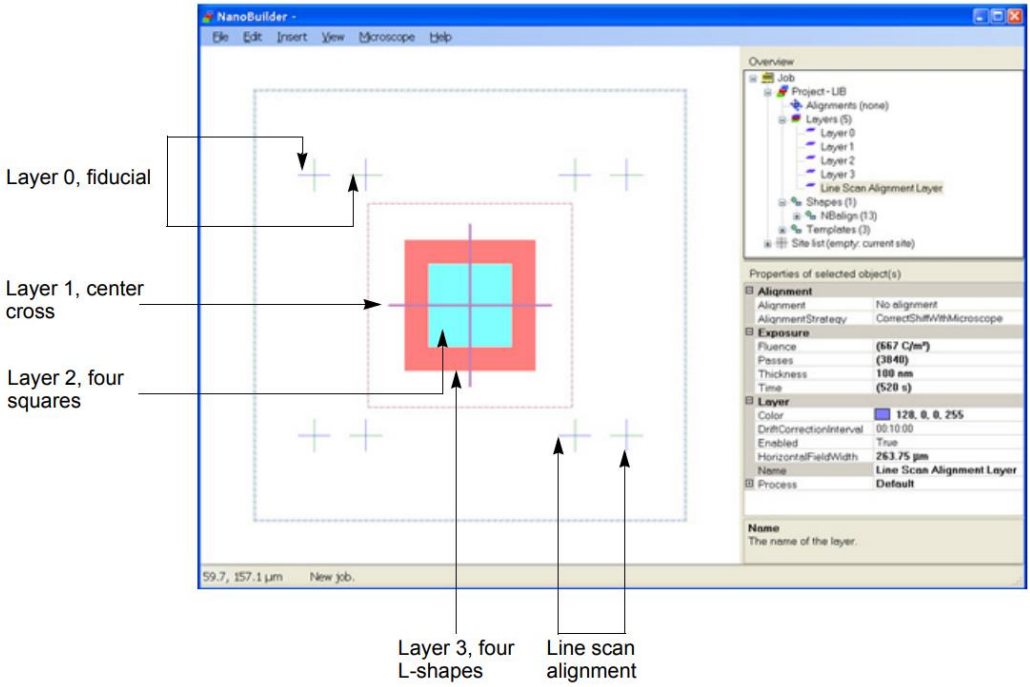
- Step 2: Configure the layers



Experiment: Configure the layers

There are 5 layers in the file

- Layer 0 is the fiducial.
- Layers 1, 2, and 3 contain the shapes to be patterned:
    - the thin cross in the center
    - the four squares around it (blue)
    - the four L-shape polygons around the four squares (red)
- The Line Scan Alignment Layer is used to align the layers.

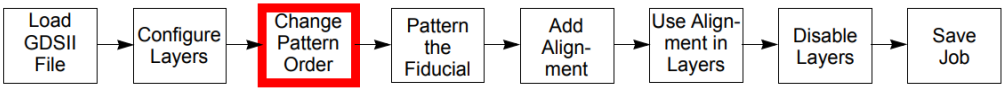


Select an object (e.g. Layer 1) and find the patterning options under “Process”

Layer	
Horizontal field width	**265 µm**
Name	**Layer 1**
Enabled	True
Color	**128, 128, 0, 128**
Process	**Modified Default**
Name	**Default**
Beam	**Ion, 30 kV, 100 pA**
Beam	Ion
Current	**100 pA**
Energy	**30 kV**
Patterning	**1 µs, 50 %, 0.15 µm³/nC**
Dwell time	1 µs
Overlap	50 %
Pitch	**(12 nm)**
Auto blank	True
Pattern sequencing	Parallel
Volume per dose	0.15 µm³/nC
Blur	0 µm
Interaction diameter	0 µm
Maximum dose per area	0 C/m²
Refresh time	0 s
Relative interaction diameter	0 %
Saturation current density	20 nA/nm²
Saturation sputter rate	0 m/s
Beam diameter	24 nm
GIS	**<no gis>**

Note: default settings can be changed in File > Preferences

- Step 3: change the order of the layers



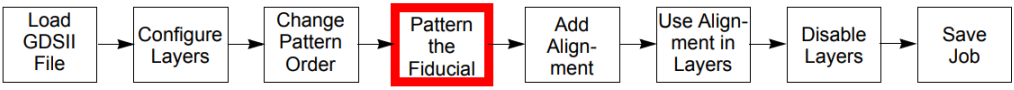
Experiment: Change the layer order

The layers will be patterned in the sequence in which they are shown

However, you want to change the order of layers so they are patterned in **decreasing beam current** order.

The layer order can be changed via drag and drop. Alternatively, use the right mouse button to click on a layer and use Move Up/Down/To Top/To Bottom to change the order layer.

- Step 4: Pattern the fiducial



Fiducial = a point or line assumed as a fixed basis for comparison, your standard or reference mark.
In this GDSII file, the fiducial is defined in Layer 0.

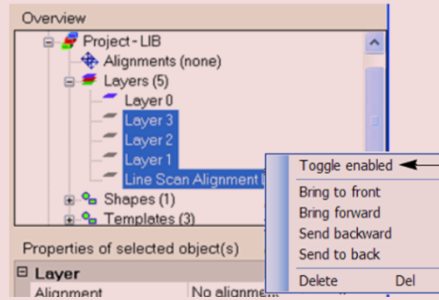
Experiment: pattern the fiducial

1. With the electron beam, navigate to an unpatterned area of at least 300 µm width.

2. Set the beam current to 1 nA (NanoBuilder).

3. Toggle all other layers not-enabled

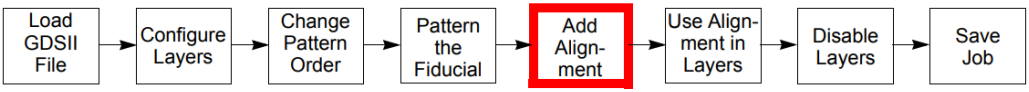
4. Save the job. If AutoSave Job is enabled, this will happen automatically.



5. Execute only Layer 0 (containing the fiducial): right-click “layer 0” in the tree view and select “Execute at current location”.

6. Verify in the e-beam that the fiducial patterning was successful.

- Step 6: Add an alignment (only when fiducial patterning was successful)



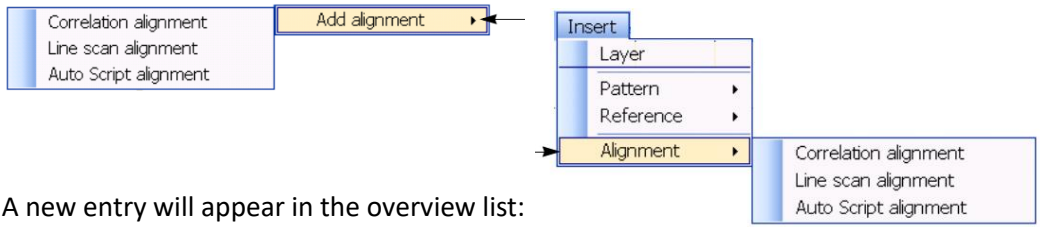
Using alignments achieves two things:

- **Align a layer to the sample**: Accurately position the patterns in a layer relative to these marks by finding marks on the sample. Even if the position relative to the sample is not critical, it is useful to align layers with respect to each other.
- **Drift correction**: Correct for drift while patterning by realigning at fixed intervals during patterning.

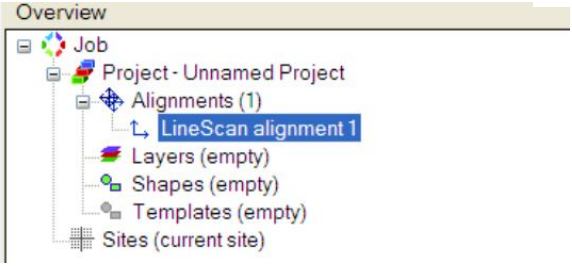
Experiment: Add an alignment

1. Select Alignments in the Overview.

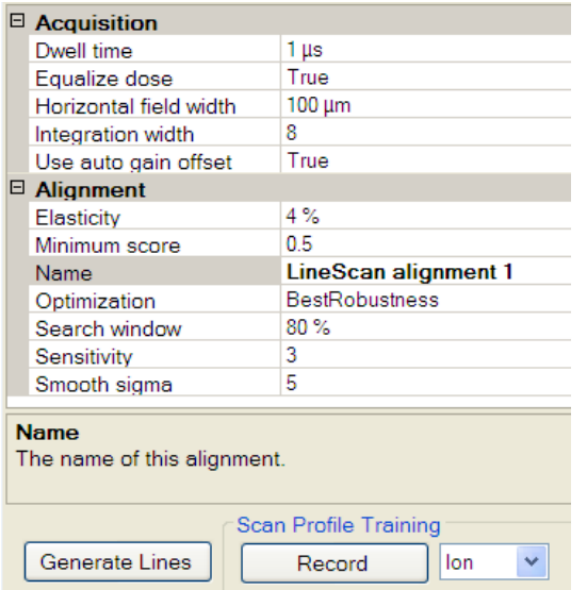
2. Add an alignment either by right-clicking the alignment selection or by selecting "Insert > Alignment". In this example, choose Line scan alignment from the list.



A new entry will appear in the overview list:



With it, a number of options are available:



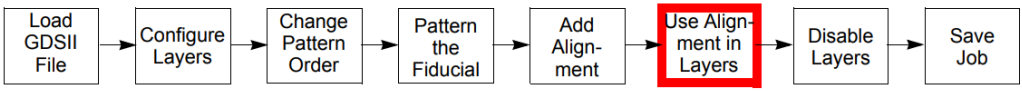
Experiment

Set Horizontal Field Width: 300 µm

Set Integration Width: 4

If you modified the design, you can re-generate the lin scans with "Generate Lines"

- Step 7: Use the alignment in other layers



After defining an alignment, the alignment must be assigned to each layer that should use it. This extra step allows having different alignments for different layers, having layers without alignment, and sharing a single alignment in multiple layers.

Experiment

1. Select Layers 1–3 (Shift + click).

2. Click in the box to the right of Alignment in the Properties area (where it says No alignment).

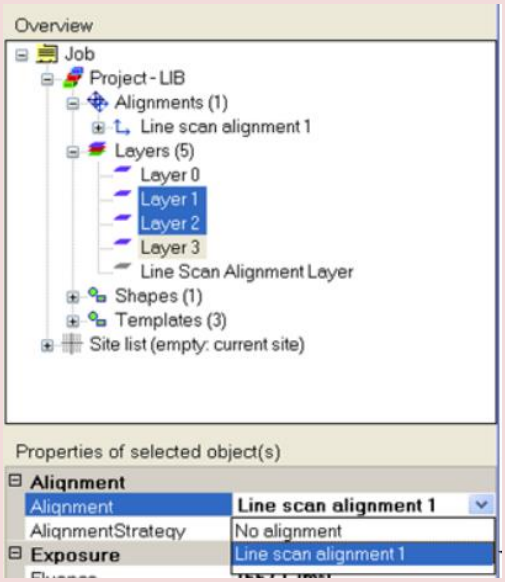
3. Click on the dropdown arrow that appears and select Line scan alignment 1.

4. Enable layers 1, 2, and 3 by selecting them and right-clicking Toggle enabled from the popup menu, or right-clicking True in the Enabled property.

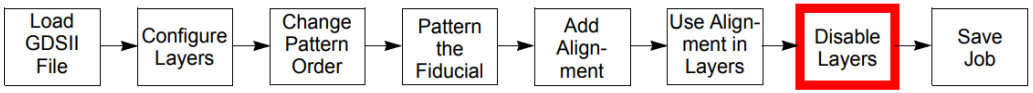
5. Set HFW to 300 µm for each layer.

6. Set the thickness to 10 nm.

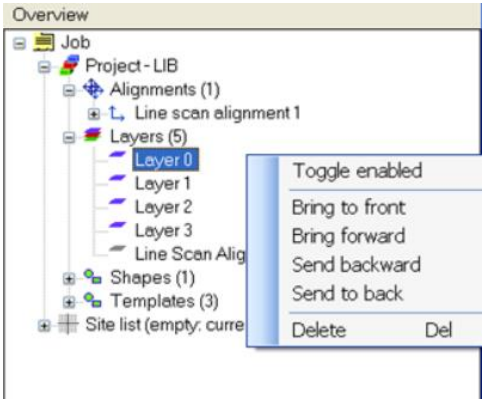
7. Cycle through each layer and set the beam current for each layer. Choose one of the available apertures. The range of typical beam current settings is 1 pA to 1 nA.



- Step 8: Disable layers not to be patterned



Layer 0 (fiducial) and the Line Scan Alignment layer help define the line Scan alignment and should not be patterned, so they should be disabled.

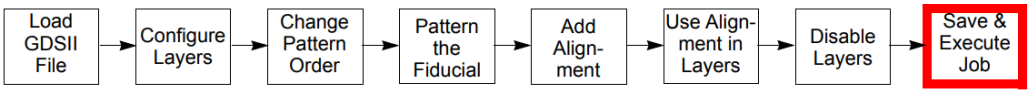


Experiment

Right-click on Layer 0 and choose Toggle enabled from the popup menu. Or, right-click True in the Enabled property.

Disabled layers have a gray icon and are not drawn in the graphical view.

- Step 9: Save and execute the job



Save the job

Use File > Save to save the job as an .nbj. file. Or use File > Save as to give it a new name. *Do not overwrite the original file!*

Note: GDSII is not savable, since that format cannot store the extra data that was added.

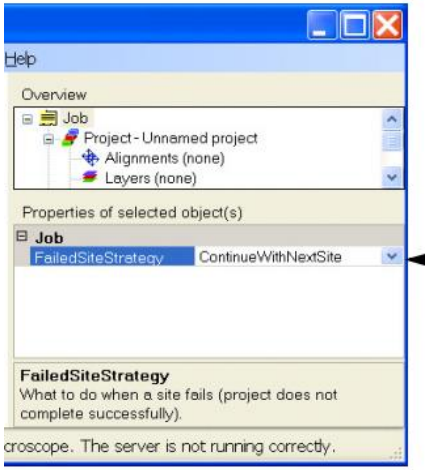
Execute the job

At this point, the color of the line scan alignments changes from blue to green, following successful line scan alignment at that line. Red indicates failure

Select Microscope > Execute to begin the patterning / executing the job. The progress is shown in the progress window and in the status bar. The progress window is minimized by clicking Hide and reopened by double-clicking the status bar.

Failed site strategy

If an error occurs during job execution, a failed site strategy message displays in the Job window.



There are two strategies:

- *ContinueWithNextSite*: Stops execution at the current stage position and continues processing at the next site.
- *AbortJob*: Stops execution of the entire job.

Tutorial: Stitching multiple write fields

Prerequisites:

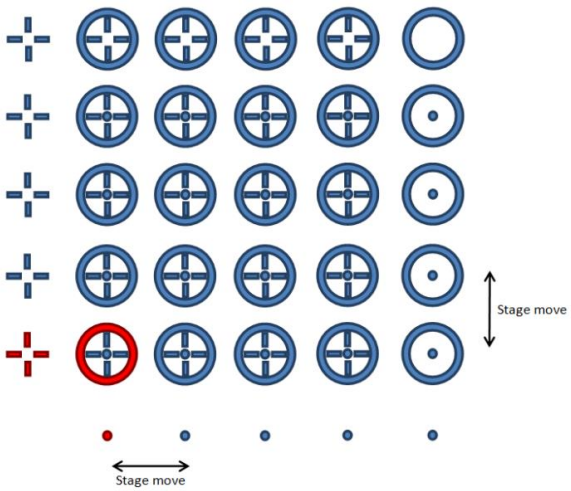
Sample loaded, stage pumped

E-beam and ion beam active

Create repetitive designs with stage movement and correlation alignment

- Goal of the tutorial

The goal is an array with each cell consisting of an outer circle (donut), a cross and a central dot. Between any two cells there is a stage movement.



At each stage location the following will be milled (shown in red):

- a large donut in the write field center
- the 4 lines that make a cross in the column to the left
- a small dot in the row below

To allow judging the alignment quality each cell consists of parts patterned at 3 different stage positions (as shown in red)

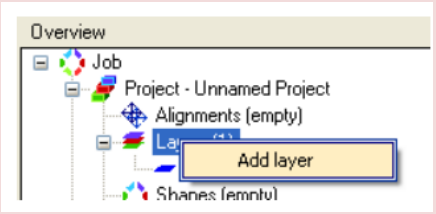
- Creating the job

Experiment

1. Start a new Nanobuilder job

2. Add new layers by right-clicking in the tree view.

Add two new layers. The first two layers will only be used to run an alignment; they will not contain any shapes.



3. Select all three layers (to set all values at once):

+ Set the horizontal field width to 50 µm.

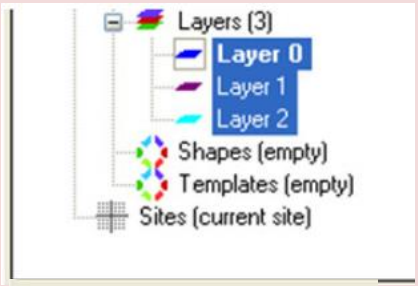
In the process section:

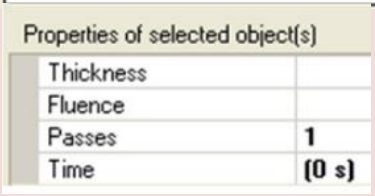
+ Expand Beam and set the Ion Beam to 10 pA and 30 kV.

+ Expand Patterning and set 1 µs dwell and 0% overlap.

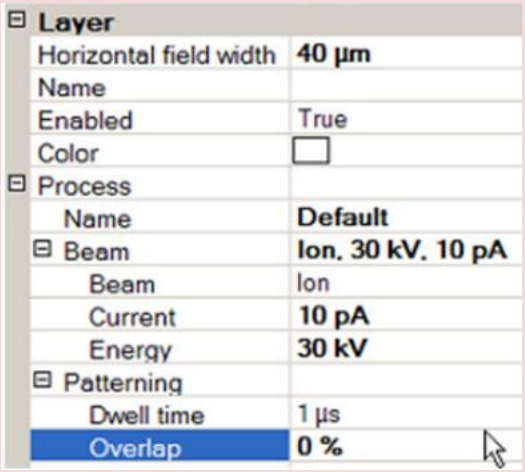
+ Ensure GIS is set to <no gis>.

+ Set up all three layers at the same time to ensure they have identical settings. The time shows as (0 s) because no shapes have been added yet.





Properties of selected object(s)	
Thickness	
Fluence	
Passes	1
Time	(0 s)



Layer	
Horizontal field width	40 µm
Name	
Enabled	True
Color	
Process	
Name	Default
Beam	Ion, 30 kV, 10 pA
Beam	Ion
Current	10 pA
Energy	30 kV
Patterning	
Dwell time	1 µs
Overlap	0 %

4. Now shapes will be added. Select **Layer 2**

5. Click in the graphical area. Press * (centers the zoom). This ensures that newly added shapes will not have an offset.

6. From the Insert menu, choose Basic Shapes > Circle.

- Set the OuterRadius to 3 µm.
- Set the InnerRadius to 2.8 µm.

7. From the Insert menu, choose Basic Shapes > Circle.
    - Set the OuterRadius to 0.5 µm, 0.
    - Set the Position to 0, -10 µm.

8. From the Insert menu, choose Basic Shapes > Path.
    - Expand the Points section.
    - Set the first point to 1 µm, 0.
    - Set the second point to 2 µm, 0.
    - Set the Line width to 200 nm.

9. Drag the Path from the Shapes into the Templates section. It now becomes available for Reference shapes.

10. From the Insert menu choose Composite Shapes > Reference (to a Template). In the dialog that appears:
    - Ensure the Template is set to Path 0.
    - Ensure the Rotation is set to 0°.
    - Click OK.

11. Repeat 3 more times, setting the Rotation to 90°, 180°, and 270°, respectively.

12. Select all 4 References and set the Position to be –10 µm, 0.

13. Select Layer 2 and set the Time to 10s.

14. Save your file.

- Creating the Alignments

You must first create a correlation alignment image that can be used as **reference image** (the image to search for). The most convenient is to acquire it in the xT UI, save it and load that image into NanoBuilder.

Experiment: STEP 1 - Acquiring the reference image

1. Load a sample that is easily marked by the FIB, like a piece of silicon wafer (for example the calibration wafer on the standard multi-stub sample).

2. Using the xT UI, set the stage to:
   - eucentric position
   - 52° tilt
   - optimize focus and stigmation for the FIB at 30 kV, 10 pA
   - Image resolution: 1536x1024
   - Dwell time: 10 µs
   - Detector: SE

3. Run Auto Contrast and Brightness (F9).

4. Move to a fresh piece of sample, with as few existing features and particles as possible.

5. In NanoBuilder, right-click on Layer 2, select Execute at current location and wait until patterning has completed.

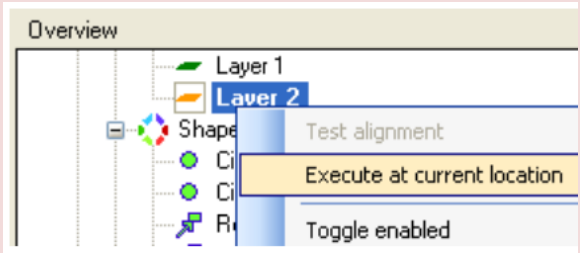
6. In the xT UI grab a single FIB image (F6+F6)

Any shift between patterning and acquisition will result in an alignment error, so don't wait too long (drift) and certainly don't use beam shift or stage moves to position the image.

7. In the xT UI select File > Save as,

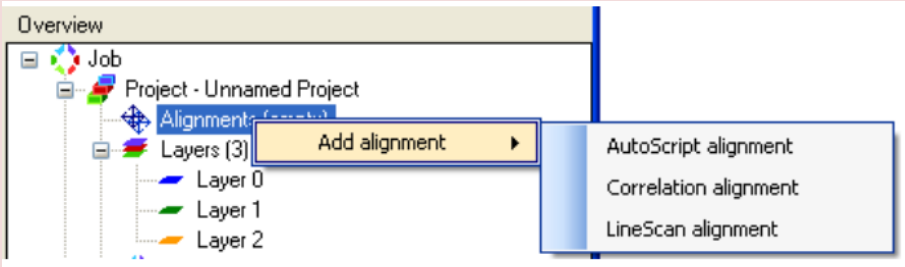
- select Tiff 8 bit gray scale Image Files
- unselect both Save Image with Databar and Save image with overlaid graphics.

Save the image in the folder where you saved the job. Right-click to execute it (without executing the other layers).



Experiment: STEP 2 – Aligning to the previous column

1. Right-click Alignments and choose Add alignment > Correlation alignment.

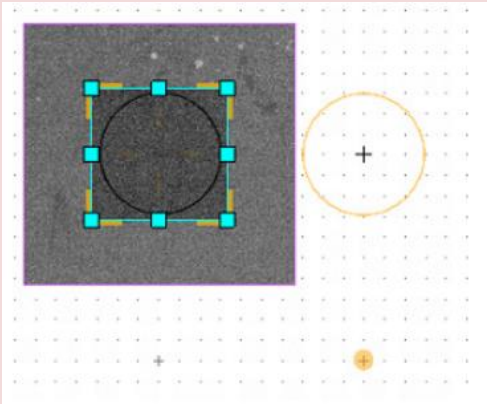


2. Click Browse in the dialog that appears, select the saved image, and click OK.

3. The new alignment is automatically selected:
   - Set the ReferenceImageOffset to –10 µm, 0
     (to make the alignment search at the previous site)
   - Set the name to “Align to previous column”.

4. Select Layer 0.
   - Set the alignment to be the newly created alignment.
   - Ensure the AlignmentStrategy is CorrectShiftWithMicroscope.

5. Click in the center of the alignment to select the Template area and resize it to only just contain the central circle (by zooming in you are able to decrease the grid pitch and make smaller steps when dragging). It is important to have as few other features visible as possible, because the alignment may otherwise try to align these to random features (dirt) on the specimen.

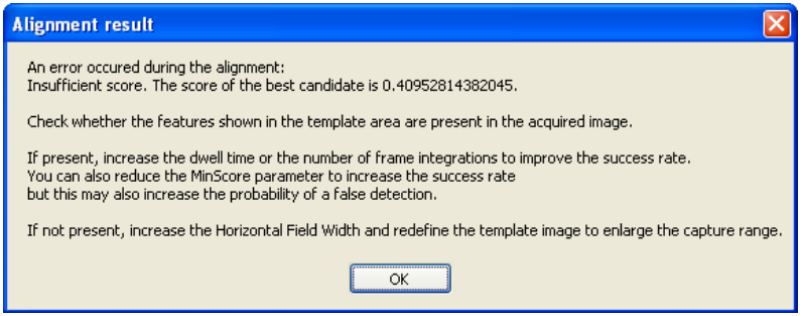


6. To test the alignment:
   - In the xT UI, make a relative stage move of 0.01 mm in x-direction (the circle needs to be about 10 microns left of the screen center).
   - In NanoBuilder, right-click Layer 0 and select Test alignment.

The alignment fails – what to do?

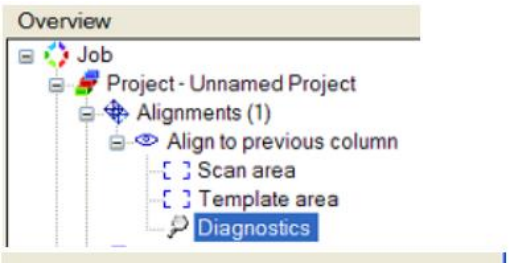
Change the minimum score

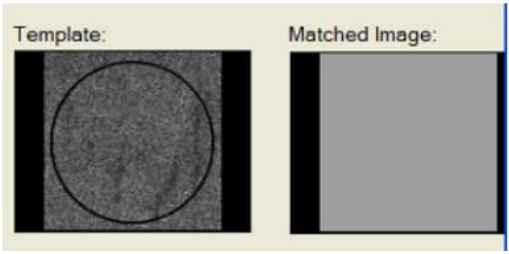
If the alignment fails the most common problem is that the minimum score is set too high. The dialog that appears upon failure tells the actual score. Select the alignment and set the MinScore to a value somewhat lower (e.g., half of) the value in the dialog.



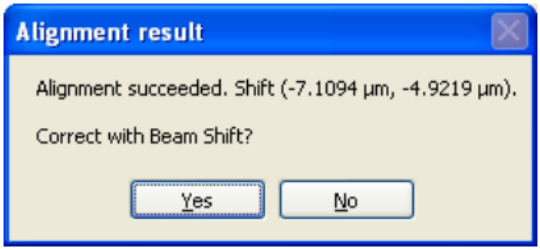
Other reasons

Try to find the cause selecting the Diagnostics item (expand the alignment in the tree view). If you do not see the template in the Matched Image then most likely the detector settings are wrong or the shift is larger than the scan area.





Select the diagnostics node to see more information about failed correlation alignments. In the above example, the quad 4 detector was set to External, resulting in a uniform gray image.
If the alignment succeeds, you get the option to set the beam shift to correct for the error. It is a good idea to select Yes and re-run the alignment. The second time should also succeed, and the measured shifts should now be very close to zero.



Experiment: STEP 3 – Aligning to the previous row

- Add a second correlation alignment, setting it up identically to the first one, except:
  + The ReferenceImageOffset is 0, –10 µm (instead of –10 µm, 0)[2]
  + Set the name to "Align to previous row".

2. Select Layer 1 and sets its Alignment to be this alignment.

3. Set the template area to only just contain the circle; this also reduces the size of the scan area and it should be possible to make the red border disappear.

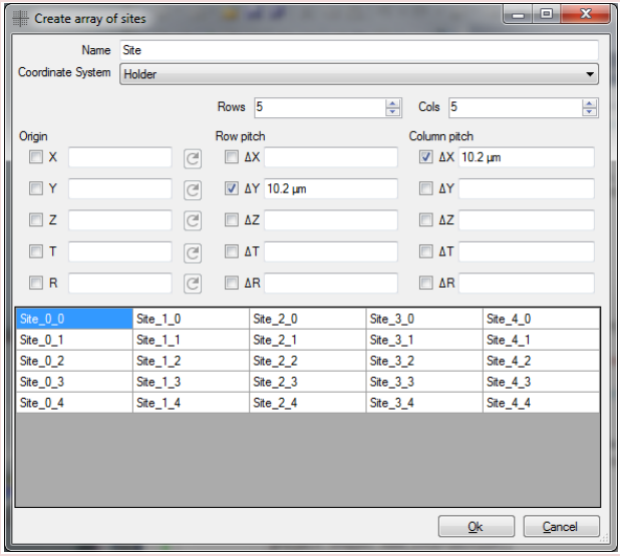
4. When testing the circle needs to be about 10 µm below the screen center, so make a relative stage move of –0.010, 0.010 mm (assuming you still are where the previous alignment was tested).

[2] This will cause it to get a red border because you are now trying to scan outside the field of view – we will fix this below

- Adding stage sites

Experiment

1. Right-click Sites and choose Add stage site array.
In the dialog that appears:
- Set the row and column pitch to be 10.2 µm.[3]
- Set the number of rows and columns to be 5 each (25 sites).
- Leave the origin blank.
- Press OK.



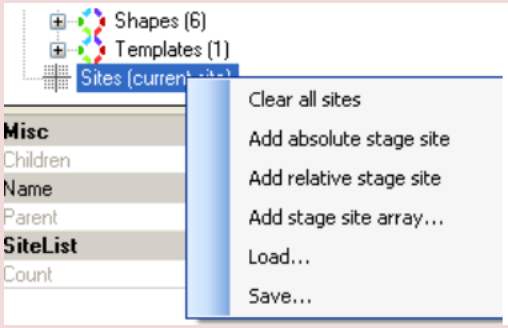
2. Select the first site, select Execute specific layers and select only Layer 2.

3. Select the next 4 sites (remainder of the first row), select Execute specific layers and select Layer 0 and Layer 2.

4. Select the remaining sites, select Execute specific layers & select Layer 1 and Layer 2.

5. Set the Failed site strategy to AbortJob.

6. Save the job.



[3] Theoretically these should be 10 µm, but we're going to introduce an intentional error so the alignments have something to correct. Note that the error is cumulative, so the last site will have 0.8 µm error.

- Executing the job

Experiment

1. Move to a fresh piece of the specimen.

2. Select Microscope > Set stage Origin from the Microscope menu to define the current position as the starting point.

3. Use Execute from the same menu to run the job.

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