Application Note

NanoPatterning Engine for CrossBeam® Workstations

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System Overview

The micromachining and structuring capabilities of the Carl Zeiss CrossBeam® workstations open a wide field of applications that range far beyond standard sample preparation.

Being able to flexibly and precisely control the focused ion beam – possibly in combination with process gases – is key in scientific and industrial research and development. For productivity applications, reliability and ease of use are major factors determining the quality of of the beam control interface.

The NanoPatterning Engine addresses these requirements by providing a highly flexible yet intuitive user interface enabling most complex and high-accuracy structuring at 16 bit accuracy.

Key Features include

- a "drawing program" style interface for the creation of complex shapes, e.g. rectangles, ellipses, rings (atom probe tip preparation), text etc.
- vector-based patterning of shapes with highly flexible raster modi and adjustable raster direction
- Array Builder utility for patterning (rectangular or radial) arrays of shapes
- 3D patterning based on greyscale bitmaps
- patterning based on user defined deflection lists
- parallel patterning of shapes each with its own distinct parameters such as beam spacing, scan strategy or dwell time
- real-time control during processing to optimize position (nudge), depth/dose or rotation of patterns
- real-time visualization from the perspective of the patterning beam as well as live SEM imaging of the patterning process
- customer designed operational recipes to simplify complex processes, e.g., material deposition, to give superior results under any conditions
- ability to control and integrate stage movements and gas delivery
- advanced image display and real-time processing capabilities for enhanced end-pointing and productivity

For higher demands a software extension is available that provides additional functionality such as

- patterning of outlines and exclusion of patterning using void regions
- performing set operations such as union, intersection, and difference of shapes
- threshold milling
- overlap resolution across multiple shapes
- auto contrast correction while milling
- AVI session recording

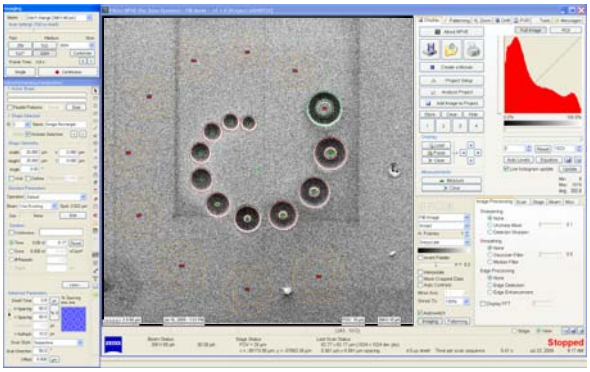


Figure 1: Screenshot of the NanoPatterning Engine User Interface

We make it visible.

Selected Features

- NanoPatterning Parameters

Figure 2 shows the NanoPatterning parameters control panel. All options such as shape parameters and execution control are easily accessible via the icon bar on the right. For each shape the dimensions, patterning parameters such as dwell time, spacing, refresh times (for deposition) and scanning strategies can be set up individually per shape. Saving and restoring shapes is possible at any time.

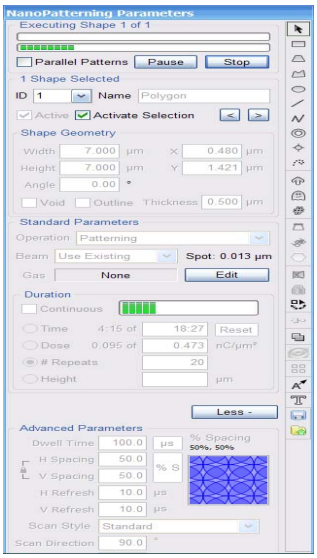


Figure 2: NanoPatterning parameter control panel

- Operations Editor

The Operations Editor is shown in Figure 3. It is designed to build, save and automatically apply complex "operation recipes" for gases and nanomachining, accounting for instrument settings such as aperture (beam current) selected, accelerating voltage, focus, etc. It increases the ease-of-use and allows novice users to readily apply the methods developed by their group's experts.

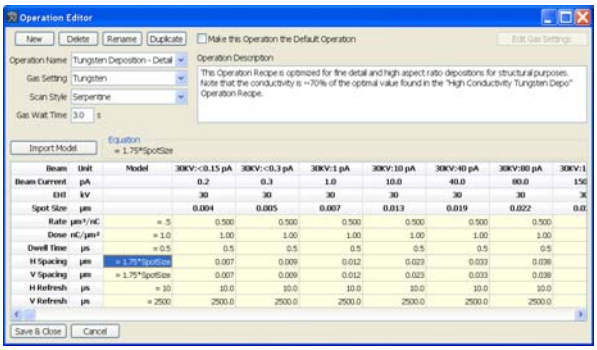


Figure 3: Operations Editor

- Array Builder

Figure 4 shows the GUI of the ARRAY BUILDER. This is a significant design-of-experiment, process development and optimization tool. Automatically "clone" an array of shapes, varying the shape size, rotation and patterning parameters including vector spacing, dwell time, refresh and retrace times, focus, stigmation, etc. according to user definable functions. Creation of complex shapes can be accomplished in a matter of minutes.

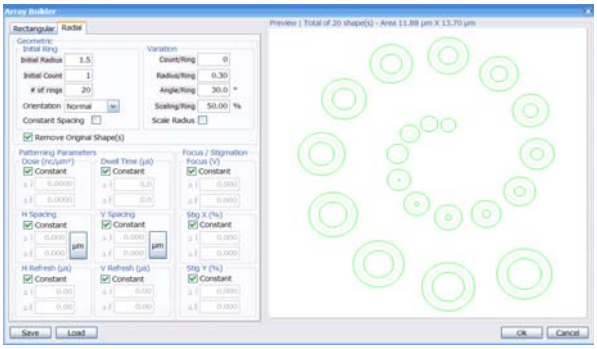


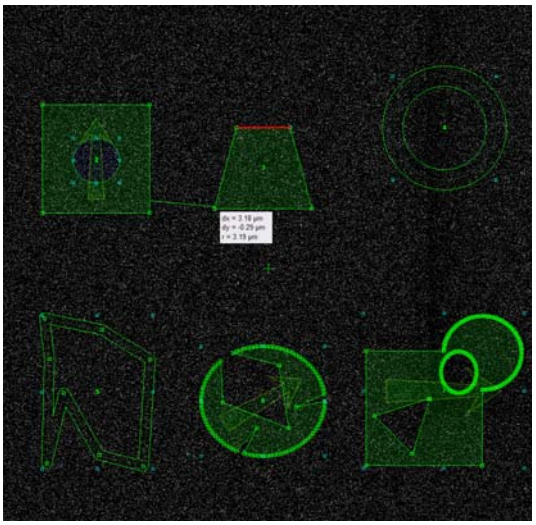
Figure 4: Array Builder

Examples

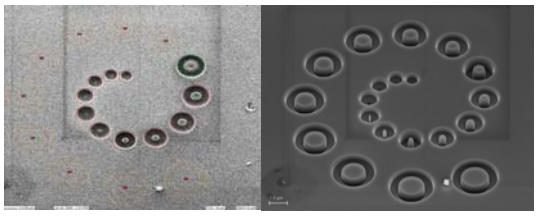
In the following a few illustrative examples show the broad applicability of the NanoPatterning Engine.

- Various patterns generated using the parameter control panel of Figure 2 :

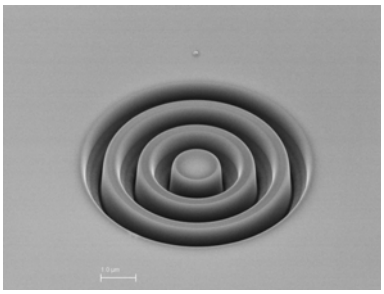
From top left to down right: overlay of rectangle and circle where the ellipse is defined as “void”, trapezium, ring, polygon with “outline” definition, circle converted to polygon with node edit, combined shape created by repeated operations such as “union” and “difference”; the green arrow shows the adjustable scan direction.

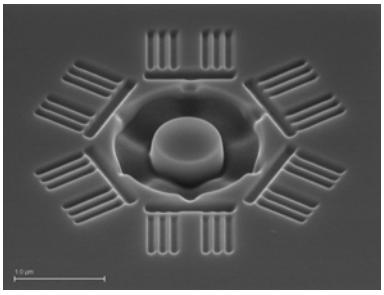


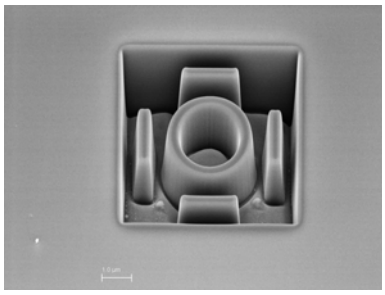
- Different patterns generated using the array builder utility:



Top row shows spiral from Figure 4. Left: perspective of the patterning beam, right corresponding SEM view image.

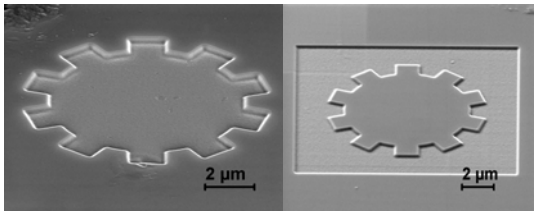




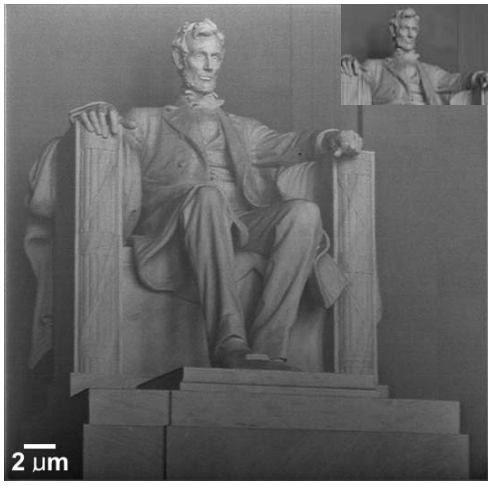


- Shapes created using ion beam deposition.

  Gear wheel created by simple milling (left) and using the void utility (right). The elevated gear structure has been created by defining a rectangle, using set operation to "subtract" the gear and then defining the gear as void.



- 3D nanopatterning based on greyscale bitmap image. Example shows a "NanoLincoln" (large image) and the original photography of the Lincoln Memorial (inset)



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