A New Tool for Automation of Focused Ion Beam Bitmap Milling of Two-and Three-Dimensional Micro and Nanostructures

Jairo D. Narro[1] & Rosa E. Diaz[2]
[1.] Department of Bioengineering, University of Engineering and Technology, Lima, Peru.
[2.] Birck Nanotechnology Center, Purdue University, West Lafayette, IN, United States
jairo.narro@utec.edu.pe | rdiazri@purdue.edu

INTRODUCTION

- Focused ion beam (FIB) microscopes are widely used for the fabrication of micro-and nanostructures with high precision and control [1]. This technique generates a beam of accelerated ions that collides with a material to remove atoms from its surface.
- Bitmap files are used to store the design information of the micro- or nanostructure and define the milling parameters.
- The grayscale value of each pixel determines the dwell time, while the pixel density and the ion beam current determine the overlap ratio [2]. 2D structures have a constant dwell time, while 3D structures have a variable dwell time.
- Depending on the complexity of the structure, the generation of bitmap files can be arduous and time-consuming. In addition, poorly selected processing parameters and the effects of redeposition and variable sputtered yield can lead to considerable deviations from the ideal structure [3].
- Therefore, it is important to develop software tools that calculate and control processing parameters and automate this part of the FIB milling process.

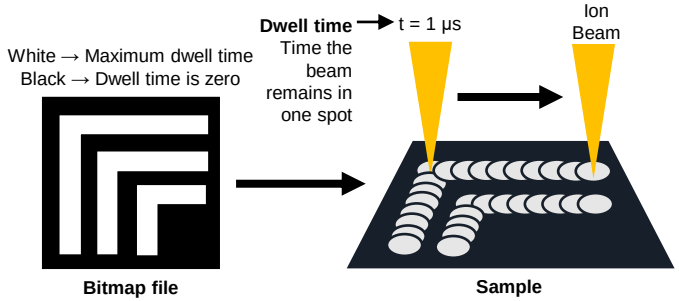

Figure 1. Bitmap milling process with a Focused Ion Beam

OBJECTIVES

- Automate the generation of bitmap files for the fabrication of patterns and arrays of different geometries with a Focused Ion Beam (FIB).
- Evaluate the 2D and 3D structures fabricated with the generated bitmaps.

METHODOLOGY

- We developed a Graphical User Interface in Python using the Tkinter module.
- The bitmap size (number of pixels) is defined by the ratio between the dimensions of the milling area and the pitch value in the x and y direction.
- The resolution of the structure is affected by the beam diameter. A smaller beam diameter will allow a larger number of pixels within a given milling area and higher resolution. However, a larger number of pixels will increase the fabrication time.
- The patterns generated with the interface can be saved as a 24-bit bitmap file and then imported into the FIB system (Helios G4 Dual Beam System).

GRAPHICAL USER INTERFACE

The tool is available in the GitHub repository: https://github.com/jaironarro/bitmap_generator_fib
The repository can also be accessed by scanning the QR code.

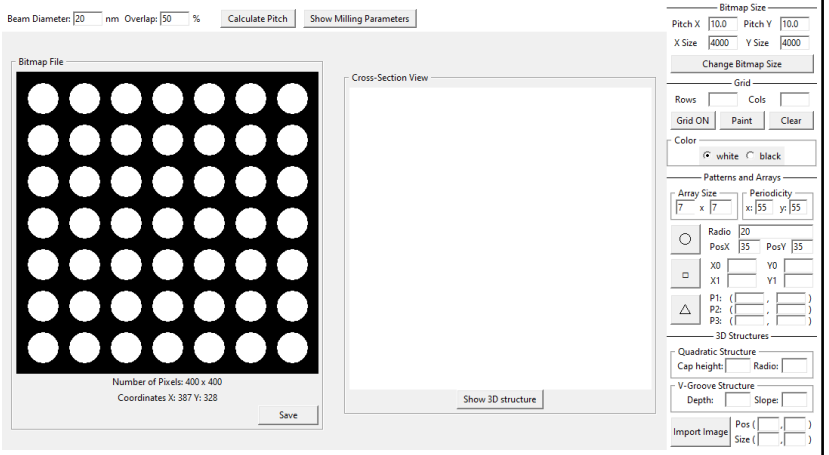

Figure 2. Nanohole array generated with the Interface. The milling area is 4um x 4um, with 7x7 nanoholes of 400 nm diameter and 550 nm spacing.

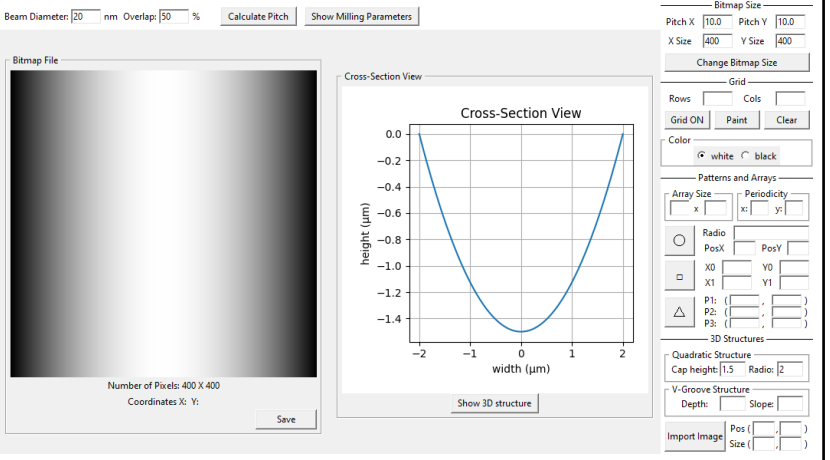

Figure 3. Bitmap generated for a quadratic microstructure and its corresponding profile function.

RESULTS AND DISCUSSION

- The developed GUI can generate bitmap files for arrays of different geometries, including circles, squares, and triangles.
- The interface can generate a suitable grayscale for 3D structures by defining the profile function. Currently, this option is available for quadratic and v-groove structures.
- For 3D structures, errors and deviations between the ideal and fabricated structure can be reduced by optimizing the grayscale values of the bitmap. This can be done by using computational methods and simulation models that include the effects of redeposition and variable sputtered yield [3, 4].

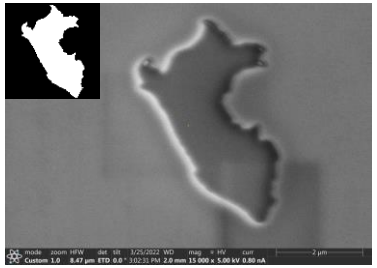

Figure 4. SEM image of the Peruvian map fabricated on a silicon surface.

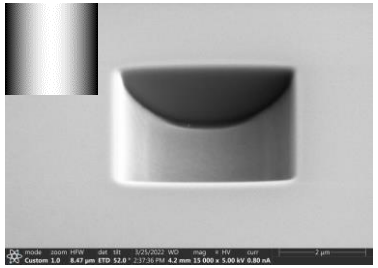

Figure 5. SEM image of a quadratic structure fabricated on a silicon surface.

CONCLUSIONS

- We developed a Graphical User Interface in Python that enables fast and automatic generation of patterns and bitmap files for the fabrication of 2D and 3D micro-structures with a focused ion beam.
- We were able to fabricate 2D and 3D structures using bitmap files. Combining computational models with the developed interface would result in a more powerful tool whose effectiveness can be evaluated in future experiments.

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