So simple, yet so difficult – towards reliable FIB milling of variable surface topographies

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Short summary: Focused ion beam processing is ideal for the prototyping of high-fidelity 3D components, particularly for quantum applications. However, the actual identification of suitable beam and patterning parameters still relies on personal talent and experience. In my lab, we aim to removing these hurdles by implementing calibration-based and physics-informed pattern generation.

Abstract:

Prototype development often relies on direct writing techniques using focused ion beams for top-down 3D shaping of topographies [1]. Direct writing with charged particle beams is based on a digital process in which the beam remains at a specific position for a certain time and is then moved on to remain there again. The sum of these beam positions forms the beam path, and depending on the mass of the primary particles, the substrate is either sputtered and/or modified, or new material is deposited along this path. To enable complete control of the beam path and allow for automated large-area patterning, we have developed the Python-based modular pattern generator FIB-o-Mat [2]. However, determining suitable parameter sets for the actual pattern generation currently still requires extensive experience and a talent for “educated guessing and intuition.” In practice, these effects lead to long and inefficient optimization cycles when high-precision surface profiles are required. My goal is to eliminate these hurdles in the application of these techniques by establishing model-informed and calibration-based 3D-FIB-o-Mat tools. The first step was to extend the Mill class of FIB-o-Mat to enable the generation of dwell time distributions for arbitrary functions representing the target shape. The second step in this direction is the implementation of user-friendly calibration routines for material removal and deposition. The third and most challenging step is to identify and implement suitable continuum models that provide a predictive description of the involved linear (e.g., angle-dependent material removal rate), non-local (material redeposition), or even non-linear (e.g., curvature-dependent sputtering) processes, and to efficiently address the problem of determining their governing parameters. I will take you on a journey through these developments, illustrated by the fabrication of a quantum-ready solid-state immersion lens in diamond [3].

References

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