Novel nanopatterning strategies for focused ion beam lithography of nanophotonic structures

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Focused ion beam lithography (IBL) offers nanolithography process channels that are complimentary to those provided by electron beam lithography (EBL). IBL allows for resistless nanofabrication, thereby reducing process complexity for rapid prototyping and making possible the direct writing of, and on, 3D structures. IBL is therefore enabling a growing range of unique applications and is an active area for instrumentation development.[1]

The physical interactions underlying IBL are different than those underlying EBL. In addition to the secondary electron generation that is common to IBL and EBL, IBL brings in addition sputtering and redeposition effects. Sputtering, the key mechanism for focused ion beam milling, is a complex process that depends on several factors, such as crystal orientation, surface topography, surface diffusion, ion implantation, and the stoichiometry of the solid. Redeposition is a less desirable mechanism that is ubiquitous in focused ion beam milling and has a similar complexity as sputtering. These additional physical complexities associated with the IBL technique call for more flexible beam deflection strategies than are typically available for EBL.

As for any lithography instrument, write times dictate the instrument's stability requirements. The focused ion beam instrument's native stability alone is not enough to meet the challenge of the most demanding IBL patterns. Therefore, as for an EBL instrument, an IBL instrument needs low overhead to maximize the portion of the write time where the beam is on the sample, as well as sophisticated control algorithms to compensate for the instrument's instabilities, thereby maximizing the fidelity and minimizing the time for the nanolithography task.

We used the Raith ELPHY *MultiBeam* nanolithography system fitted to a FIB-SEM instrument for the IBL fabrication of a photonic array of elliptical structures (Figure 1). From a range of possible low-overhead patterning modes, we selected a multipass, spiral-outward patterning strategy to fill each ellipse in the photonic array (Figure 2). The multipass aspect of the patterning mitigates redeposition effects, whereas the spiral-outward aspect produces smooth edges in the resulting ellipses. As this task required several hours of IBL write time, we utilized automated beam position drift correction, which was based on an image-based mark registration algorithm.

[1] (a) B. R. Appleton, S. Tongay, M. Lemaitre, B. Gila, J. Fridmann, P. Mazarov, J. E. Sanabia, S. Bauerdick, L. Bruchaus, R. Mimura, and R. Jede, IBMM 2010 Conference Proceedings (in press). (b) A. Imre, L. E. Ocola, L. Rich, and J. Klingfus, J. Vac. Sci. Technol. B **28**, 304 (2010). (c) J. Gierak, Semicond. Sci. Technol. **24**, 043001 (2009).

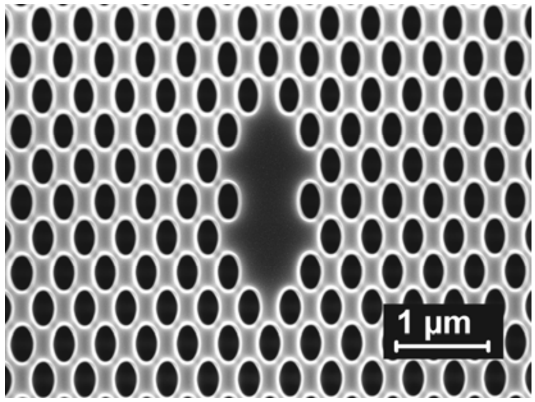

Figure 1 A photonic array of elliptical nanostructures that required several hours of continuous writing time.

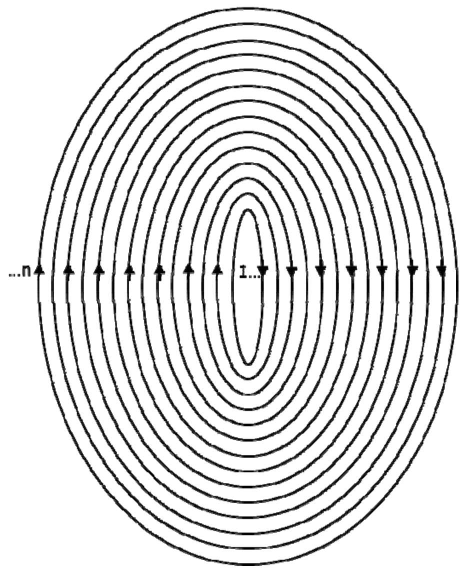

Figure 2 A schematic of the multipass, spiral-outward patterning strategy that was used to fill each ellipse in the photonic array.