Most recent Raith Innovations and Solutions for Nano- and Microfabrication, advanced Process Control and correlative Analysis

F. Nouvertné, M. Kahl, A. Casimiro, K. Keskinbora, T. Richter, P. Gnauck and A. Wscieklica

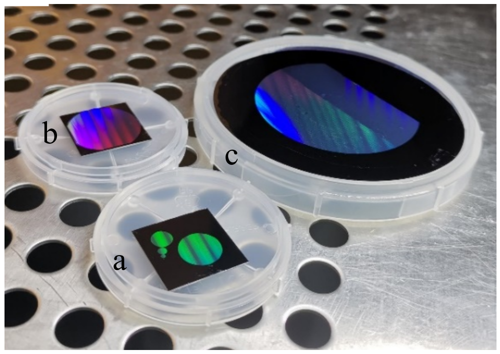
Raith GmbH, Konrad-Adenauer-Allee 8, Dortmund, 44263, Germany
frank.nouvertne@raith.com

Metasurfaces are very promising to potentially revolutionize a lot of sensing and imaging applications in consumer electronics, medicine, autonomous vehicles, AR/VR displays, and more. However, their nanofabrication implies some significant challenges due to the nature of their very complex design. Corresponding (GDSII) design data files can grow up to several hundreds of GB making it extremely challenging if not impossible to be processed efficiently with conventional EBL systems.
Here, we present a lean, fast and extremely efficient innovative EBL workflow that circumvents the necessity for generating a flat GDSII design by exploiting the algorithmic (formula-based) description of a metalens pattern. This new concept enables upscaling and successful nanofabrication of metalens structures as described in [1] or similar from typically 1mm up to a diameter of 50mm.

With nano- and microfabrication systems now also comprising single or multiple laser beams, Raith has recently complemented its technology portfolio. Single-beam laser writers enable the fabrication of extremely deep SU-8 structures up to 600 µm with perfect sidewall verticality, setting a new standard in high-aspect-ratio lithography. This precision is achieved through an advanced optical system with adjustable spot sizes and depth-of-foci, which ensures uniform exposure throughout the entire depth, eliminating issues like tapering or footing. Such capability is particularly valuable for microfluidics, where deep, high-precision channels are required for efficient fluid manipulation, and micromechanics, where robust, high-aspect-ratio features are essential for mechanical stability and functionality.

Finally, all micro- and nanolithography results and subsequent process steps need to be carefully verified, quantified and analyzed in order to ensure optimum device quality. Here, the Raith VECTOR and IONMASTER are helping with their process control and correlative analysis capabilities in order to bridge the "valley of death from lab to fab" by exploiting fully automated large area SEM imaging, metrology and SIMS analysis workflows.

[1] Mohammadreza Khorasaninejad, Federico Capasso et al., "Metalenses at visible wavelengths: Diffraction-limited focusing and subwavelength resolution imaging", Science, Vol. 352, issue 6290, 1190–1194, 2016



Diameter	Number of circles	Exposure time
0.2 mm	0.13×10^6	2 s
1 mm	3.14×10^6	1 min 4 s
2 mm	12.57×10^6	4 min 20 s
5 mm	78.54×10^6	26 min 35 s
10 mm	314.16×10^6	1 h 46 min
20 mm	$1,257\times10^6$	7 h 5 min
50 mm	$7,853\times10^6$	44 h 12 min

Figure 1: Metasurfaces with different diameters, exposed in PMMA resist with algorithmic patterning (Raith VOYAGER) at 13.4 nA: a) 0.2 - 10 mm, b) 20 mm (both on 20 mm large silicon samples), c) 50 mm (3" silicon wafer)
Table 1: Exposure Times for various metalens diameters

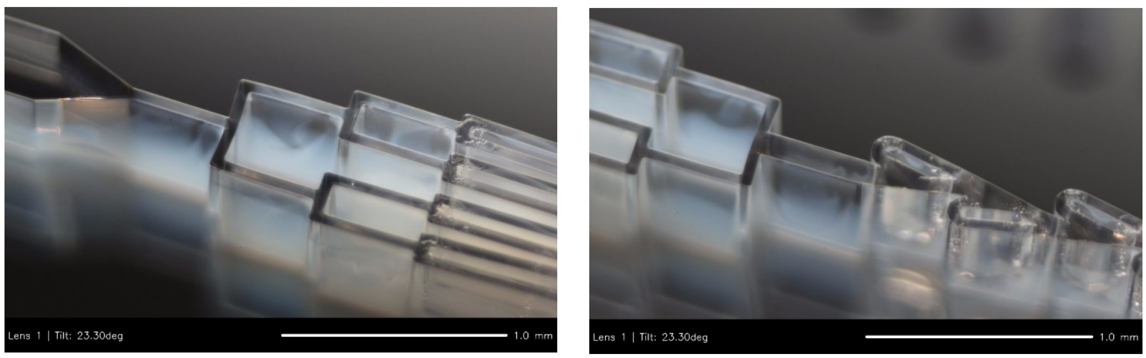


Figure 2. Cascaded mixers (left) and Tesla valves (right) exposed in 600 µm deep SU-8 using PicoMaster 200 with 375nm i-line optical module with 5-µm-wide extra-large spot size.

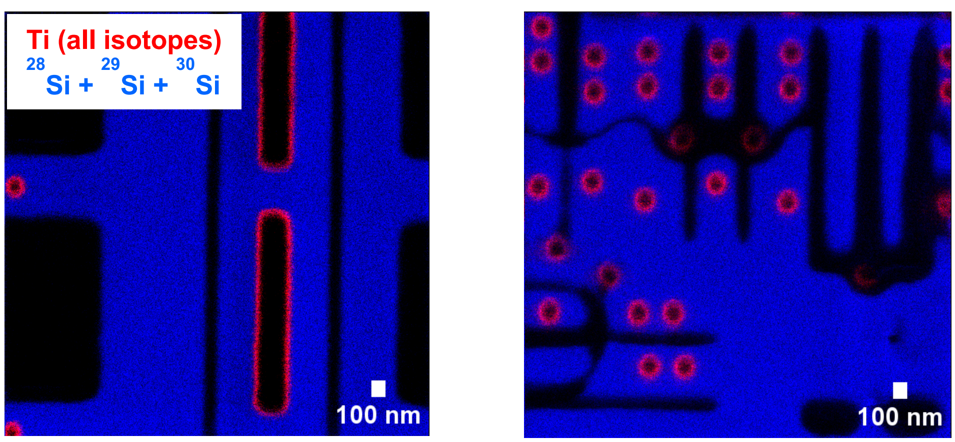


Figure 3: High resolution SIMS mapping of a microchip sample