# Self-aligned structures by a single-step through-membrane 100-keV electron beam lithography

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Patterning of aligned structures on supporting thin membranes is required in many application, such as fabrication of stacked zone plates[1] and realization of observation windows in nanofluidic channels[2] (e.g., in environmental chambers with ultra-thin electron-transparent membrane-windows for transmission electron microscopy).

Here we present a process flow to fabricate self-aligned structures on both sides of a membrane stack by means of a single-step through-membrane 100-keV electron beam exposure. High energy of the electron beam ensures that the electrons are able to propagate through the membrane stack that is coated with resist on both sides (Figure 1, a-c), while the single step exposure ensures that subsequently etched structures in the supporting silicon nitride membranes are perfectly aligned (Figure 1,d-f). Simulations of electron scattering indicate that for µm-sized structures the exposed region (containing 90% of the deposited dose) broadening is <10% for a thick ~5-µm assembly (500 nm of $SiO_2$ sandwiched between two 250 nm thick $SiN_x$ layers, with the membrane stack coated with 2 µm of PMMA resist on both sides). This corresponds well with the broadening measured from the imaged cross-sections of structures etched into the top and bottom $SiN_x$ encapsulating membranes. The broadening can be further optimized by adjusting the process parameters and reducing the thickness of the PMMA resist. The relatively small feature-broadening at the bottom of the membrane stack indicates that perfectly aligned sub-µm features are feasible.

[1] I. Mohacsi, I. Vartiainen, M. Guizar-Sicairos, O. Karvinen, V.A. Guzenko, E. Müller, C.M. Kewish, A. Somogyu, C. David, Optics Letters **41**, 281 (2016)

[2] S. Gorelick, T. Alan, A.Z. Sadek, R.T. Tjeung , A. de Marco, Nanotechnology **30**, 085301 (2019)

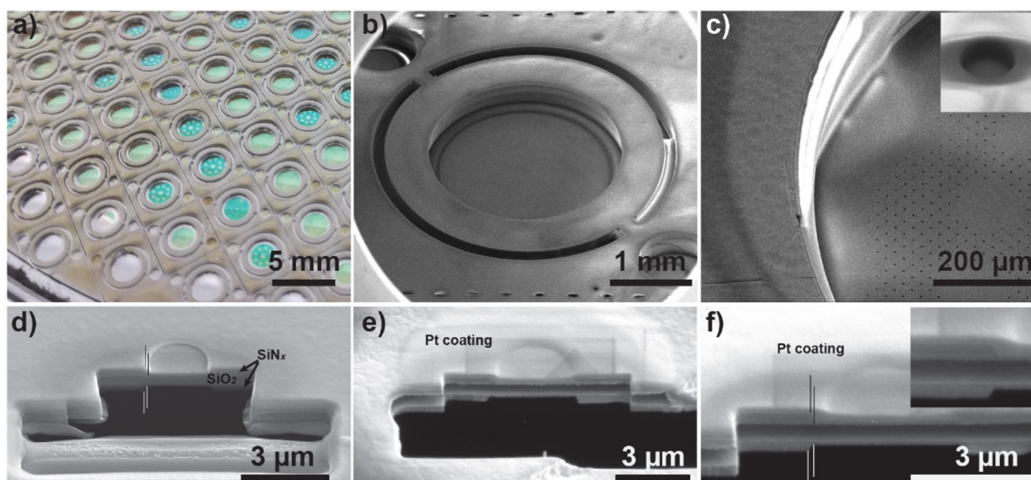


*Figure 1: Single-step through-membrane 100-keV electron beam lithography:* (a) An overview of 5×5 mm released circular membrane stacks (500-nm-thick patterned sacrificial silicon dioxide layer sandwiched between two 250-nm-thick silicon nitride layers). (b) Scanning electron microscopy (SEM) image of the bottom side of the membrane stack coated with PMMA resist. (c) SEM image of e-beam patterned PMMA layer. The exposure was performed from the top of the device (coated with PMMA as well). Due to the high energy of the beam, the electrons are able to penetrate the whole stack with little scattering and expose the resist on both sides of the membrane. Inlet shows the developed PMMA resist with vertical sidewalls. (d) The developed PMMA resist was used to etch into both top and bottom silicon nitride layers. (e,f) Cross-sections of the self-aligned circular windows in top and bottom silicon nitride membranes encapsulating a nanofluidic channel after removal of the silicon dioxide layer in sacrificial etching. The top membrane was coated with Pt to produce a clean cross-section using focused ion beam.