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Ice lithography: ice-based nanopatterning

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Almost any micro- and nanostructure, the building blocks of modern electronics, requires one and generally several lithography iterations where the desired features are defined in a sacrificial layer (resist) used in further processing. This is typically done using UV light, but to overcome diffraction limits collimated electron beams are used to resolve nanometric resolution. A typical lithography process requires multiple different tools, engineered materials and abundant solvents to create, develop, and then remove the thin resist film on the desired substrate.

Ice lithography is a novel technique which doesn't suffer from these limitations. The role of resist is taken by water, deposited directly inside the electron beam chamber on a cooled substrate to create a thin ice film to be patterned [1]. No harmful chemicals or other tools are needed. Sub-20 nm resolution was demonstrated, even on non-planar or fragile substrates which are impossible for conventional techniques [2]. An in-situ metallization process allows using the patterned ice to create seed layers for further processing or one-step nanodevice fabrication [3].

Here at DTU, we recreated an ice lithography setup and took this promising technology a step further. A scanning electron microscope was modified for cryogenic operations and ice deposition (Fig.1) and can now be used to research applications in advanced nanopatterning and nanofabrication using a variety of ices as resist.

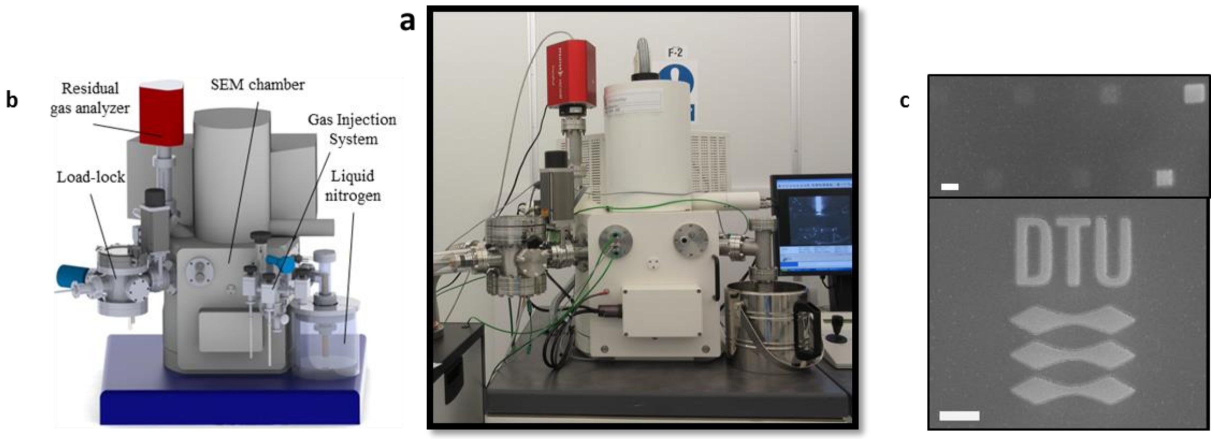

Figure 1 – Ice lithography at DTU Danchip. The modified SEM for ice lithography (a) and the original 3D model (b) used to design the custom parts. By progressively increasing the electrons delivered per unit area (c, top), the optimal dose is identified and used to reproduce arbitrary patterns on 100 nm ice films (c, bottom). Scale bars in (c) are 1 µm.

[1] King, G.M. et al., 2005. *Nano Letters*, 5 (6), 1157–1160.
[2] Han, A. et al., 2012. *Nano Letters*, 12 (2), 1018–1021.
[3] Han, A. et al., 2010. *Nano Letters*, 10 (12), 5056–5059.