Large area direct-write focused ion-beam lithography with a dual-beam microscope

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ABSTRACT

Today's focused ion beam (FIB) instruments are extensively used for small device tailoring, mask repair, and sample preparation, such as cross sectioning for microanalysis and lift-out for transmission electron microscopy and atom probe tomography. These are relatively limited tasks done localized to a particular place on the sample surface. Motivated by the wish to automate more complicated patterning tasks and achieve similar controls and performance to that achieved in electron-beam lithography, the implementation of dedicated large area direct write FIB lithography system is explored. Given that ion beam optics employs similar physics to electron beam optics, the same principles that govern electron beam lithography may be applied to FIB lithography, such as the use of pattern generators, high resolution stage, and stitching correction. Writing strategies have to be adjusted [1] however due to re-deposition, and other characteristics of an FIB. A dual-beam FIB is a versatile instrument that can perform sputtering, deposition, or chemical surface modification dependent on ion beam parameters, controls and assisting gases. Relevant techniques that utilize ion beam parameters and patterning strategies exist [2-4], but have not necessarily been supported by EBL software.

We have investigated the use of FIB direct-write lithography for large area (multiple write-field) patterning in an FEI Nova NanoLab 600 Dual Beam microscope. Our system is configured with a 100 nm resolution X-Y stage and a Raith Elphy Lithography control interface, with its own integrated 16-bit DAC pattern generator and software. Key issues with regard to configuration, process parameters and procedures have been addressed. Characterization of stitching errors and use of offset patterning and in-field registration marks to correct stitching errors were performed, and a test microfluidic device covering an area of 1 mm x 1.4 mm was successfully fabricated. Examples of large area fabrication using stitching techniques are shown in Figure 1 and 2. We find that due to higher beam deflection speed in FIB systems compared to typical 10 MHz electron beam lithography tools, FIB lithography can be almost as fast as electron beam lithography on for typical mill depths of the range between 200 nm to 500 nm. This opens the door for a large suite of applications in research environment, patterning materials for which reactive ion etch based pattern transfer is difficult or impossible due to material or device constraints [5].

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References

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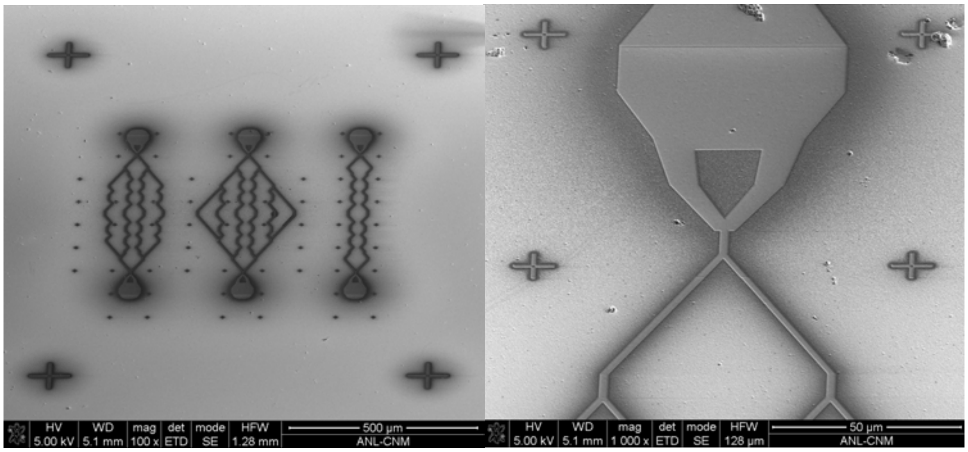

Figure 1. SEM micrographs of a 1 mm x 1.4 mm pattern exposed using FIB lithography. Small crosses indicate locations of field boundaries.

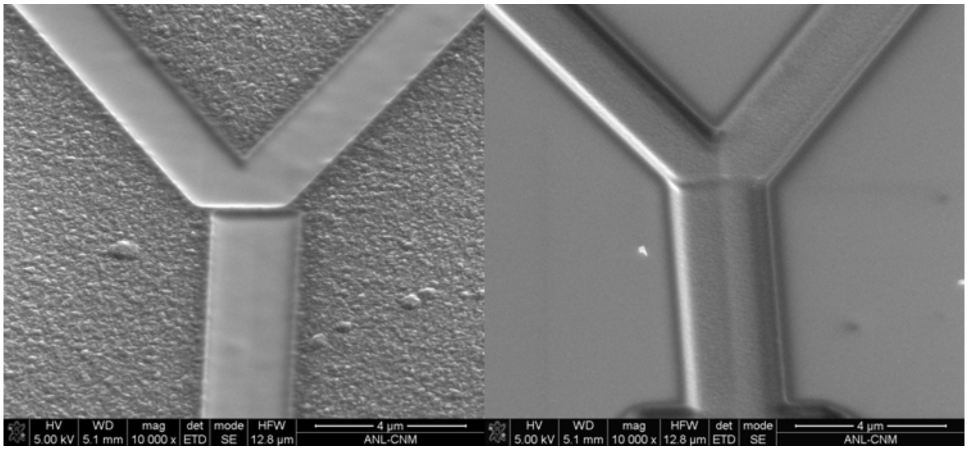

Figure 2. SEM micrographs show the effect of offset patterning, fixing severe stitching errors. (left) Stitching error that would render a microfluidic device useless. (right) Same pattern exposed with offset patterning.