# Advances in Ion Beam micromachining for complex 3D microfluidics

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The focused ion beam / scanning electron microscope (FIB/SEM) is a powerful tool used for sample analysis and characterization. When equipped with a sophisticated pattern generator and lithography technology it can expand its use to new applications in nano- and micro-fabrication. Ion beam micromachining is akin to electron beam lithography, where a beam of charged particles are steered to draw structures contained in a computer aid design (CAD) file. Unlike electron beam lithography, one can program arbitrary depths by manipulating the dwell time, or dose, of a particular structure. We have been working on this topic for several years now [1-2] and are able to show that the ion beam tool can be used for real microfluidic applications [2].

3-D microfabrication currently is mainly constrained to excimer lasers [3-4] and therefore is inherently diffraction limited. Grey scale lithography is also used for 3D structures but has limited capability. On the other hand, FIB micromachining can scale down below the diffraction limit with no change in the technique and almost unlimited depth bandwidth.

In this work we present an application where the bottom of microfluidic mixers is texturized using an FEI Dual Beam Novalab 6 with a Raith Elphy pattern generator. A micromachined mixer is shown in Fig 1. The bottom of a focusing mixer, previously fabricated with standard lithography and etching to provide a base depth of 25 μm, is then further modified by milling away strips to create a graduated and continuously changing profile. The mixer is over 400 μm long and 30 μm wide. The deepest ion beam milled regions are over 40 μm deep. The current used was 21 nA, with a standard Ga ion gun. Exposure time was 10 hrs.

Although the exposure time may seem long, it is clear that existing technologies such as Xe ICP gas source guns (100 nA, 2X milling efficiency) can cut down the exposure time easily by a factor of 10. This would allow 3D ion beam micromachining to be used for practical applications in industry, if accompanied with standard replication techniques.

Pros and cons of different patterning strategies regarding pattern boundaries, redeposition control, and pattern data organization, will be discussed.

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References:
1. A. Imre, L. E. Ocola, et al., J. Vac. Sci. & Technol. B, 28, 304, (2010)
2. E. Palacios, L. E. Ocola, A. Joshi-Imre, et al.,, J. Vac. Sci. Technol. B 28, C6I1 (2010)
3. Y. Liao, et al., Lab Chip, 12, 746, (2012),
4. A. Ródenas, et al., Proc. SPIE 8542, 854217, (2012)

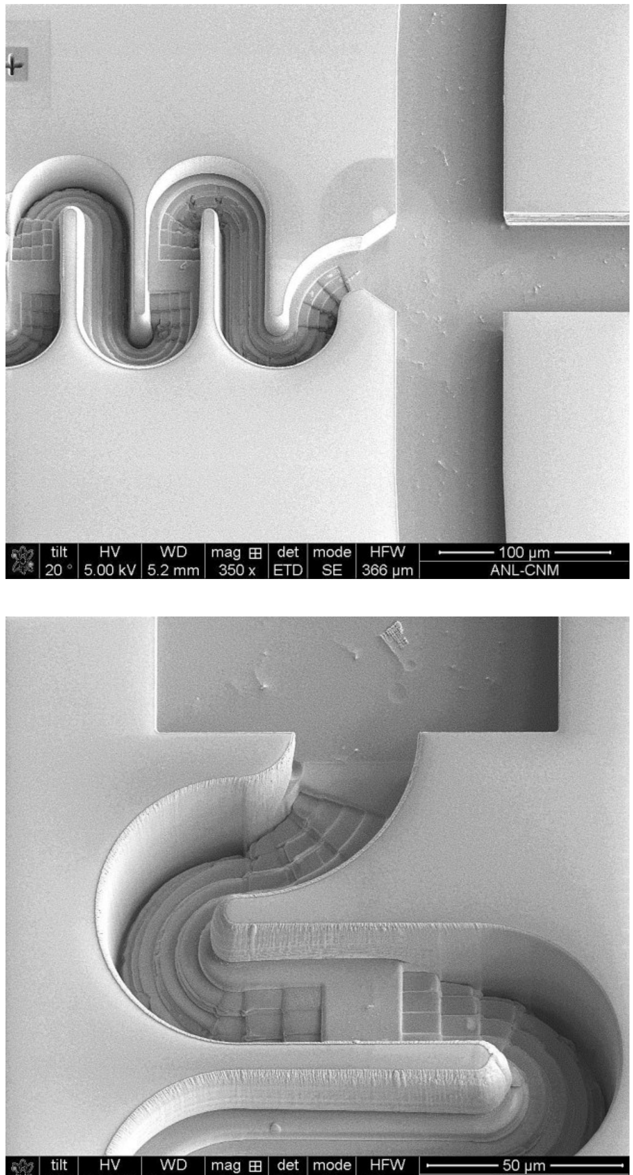


*Figure 1. 3D texturized serpentine mixer*. SEM micrographs of a focusing microfluidic mixer with an ion beam micromachined texturized bottom using an FIB SEM. The ion beam exposure had to be aligned to an existing fabricated structure using standard alignment marks. (*top*) Inlet of the focusing mixer. (*bottom*) Exit of mixer. The sample is tilted at 20 degrees. The deepest ion beam milled regions are over 40 μm deep.

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