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Custom-tailored nanofluidic channels utilizing a FIB

H. D. Wanzenboeck, E. Bertagnolli
Vienna University of Technology
Institute for Solid State Electronics
Floragasse 7/1
A-1040 Vienna, AUSTRIA

Microfluidics is an emerging technology that has proven useful for studying and controlling molecular interactions in a strongly reduced sample and reagent volume. This novel method has numerous application areas in chemical analysis, in clinical diagnosis and process control of liquid systems. In contrast to macroscopic fluid processing systems. the small cross-sections of the microchannels unleash novel possibilities for processing as the liquid-surface interaction plays a dominant role in microfluidics. Dependent on the shape and size of the channel cross section diffusive transport may cover large fractions of the fluid channel at microscale dimensions. The geometrical design of the microfluidic channel gains a crucial role in microfluidics.

The majority of microfluidic devices is fabricated by micromachining techniques utilizing lithographic patterning with photomasks in combination with isotropic and anisotropic wet or dry etching. In this work we have employed a focused ion beam tool for fabrication of microchannels. This versatile method is proposed to be the superior approach for new, innovative concepts for 2 reasons. No expensive photomasks are required and the geometry and etching depth can be chosen individually for every device area processed. With FIB processing channels below 100 nm with could be realized. It was also demonstrated the channels with a different depth may be processed within the same process step, while 2 different process cycles would be required by traditional micromachining techniques. This flexibility renders FIB the ideal tool for new device developments. The ion beam with a focus below 20 nm allows to fabricate smallest channels in the sub-100 nm region. Furthermore, direct-write deposition by a FIB allows to directly introduce electrodes by a locally confined chemical vapor deposition (CVD) of the electrode material. Within the same process steps the metal electrodes may be deposited on any deliberately chosen position within the microchannel.

A focused gallium ion beam was employed to sputter material from the otherwise flat substrates of silicon, silicon dioxide glass and infrared transparent CaF_2. The channel width was varied between 100 nm and 20 µm. A channel depth gradient could be fabricated to gain a shallow channel for a fixed width. Tasking advantage of the easy pattern generation with the Fib, complex exemplary structures with meandering channels, mixer chambers and and heat sinks were fabricated. Utilizing FIB-induced tungsten deposition from $W(CO)_6$ allowed to position and deposit metal microelectrodes within the channel. This is especially helpful, as further lithography and metal deposition processes are redundant.

With this work it has been demonstrated that FIB processing is a suitable and versatile fabrication method of microfluidic devices. This maskless approach allows to exploit nanochannel devices with ground-breaking flow conditions. The low-directing properties micromachined elements can be optimized with different channel lengths, depths and opening angles to realize diffusers, mixers, valves micropumps and electrodes for electrophoresis.

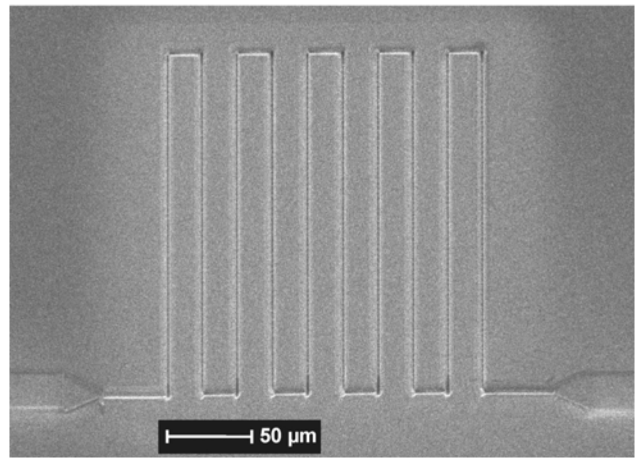
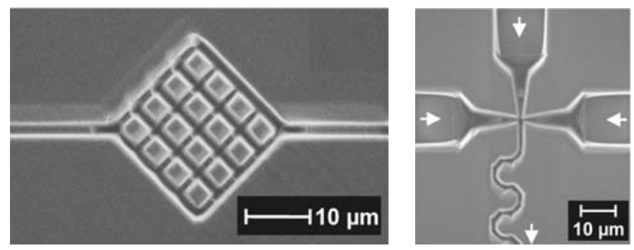


Fig. 1 A 2,2 µm long meander microfluidic device with a 1 µm wide and 1 µm deep channel fabricated by maskless FIB-sputtering of a silicon oxide/silicon substrate.



(a) (b)

Fig. 2 Advanced microfluidic designs realized by FIB-processing. No photomask was required.