Optimization of a Self-Closing Effect to Produce Bottle-Shaped Nanochannels in Quartz

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The spatial control of molecular motor protein function, using nanochannels, is of great interest for the development of commercial devices in diagnostics[1] and high-throughput drug screening devices with molecular motors as targets[2, 3]. In this study we have fabricated 100-300 nm wide nanochannels, completely sub-surfaced on fused silica chips, which can be interfaced with a micro-fluidic system. Our micro-fluidic system is designed to allow for fast switching of the chemical environment surrounding the molecular motors with minimal influence on their directional motion. This will be achieved by changing the chemical environment above the nanochannels (using flow perpendicular to motor motion), and allowing the chemical substances to diffuse in and out of the channels via a 5-10 nm wide slit on the top of them.

We here present a modified fabrication method where we utilize a self-closing effect of SiO_2 to fabricate nanochannels sub-surfaced in fused silica with a thin slit on top. The following process steps are used (Figure 1): a) evaporation of 20-30 nm thick Si layer, spin-coating of resist and EBL exposure to open narrow lines in it, b) RIE of Si layer using a mixture of $SF_6/CHF_3/O_2$ to form an opening in the Si mask, c) isotropic wet etching of the fused silica substrate in a buffered oxide etch solution to form the nanochannels, d) removal of the resist layer and thermal oxidation of the Si mask to decrease the gap and produce a well-controlled slit. The oxidation process of silicon results in a volume increase of SiO_2 by a factor of 2.27. Lateral expansion of SiO_2 leads to partial or complete closure of the nanochannels. Figure 2 show the SEM images of the nanochannels with partially open and closed channels after oxidation.

A preliminary process[4] demonstrated the self-closing effect, but also revealed a drawback. Reactive ion etching of Si in SF_6-based gas mixture is very fast and almost isotropic during the first few seconds. Lateral etching of Si under the resist may result in variation of the slit width. Such variation can now be avoided by including three additional process steps to the previously described fabrication scheme.

After evaporation of Si a short oxidation in rapid thermal processing oven is performed to obtain 10-20 nm thick SiO_2 mask on the top of Si. Next, EBL patterning is followed by two anisotropic RIE processes: SiO_2 etching in CHF_3-based RIE and Si etching in Cl_2-based ICP-RIE. The modified fabrication scheme has demonstrated good process control and will be described in detail together with applications of the nanochannels. *Acknowledgement:* This work was funded from the EU 7-th Framework Programme (FP7/2007-2011), grant agreement n° 228971 (Molecular Motors-based Nano Devices –MONAD).

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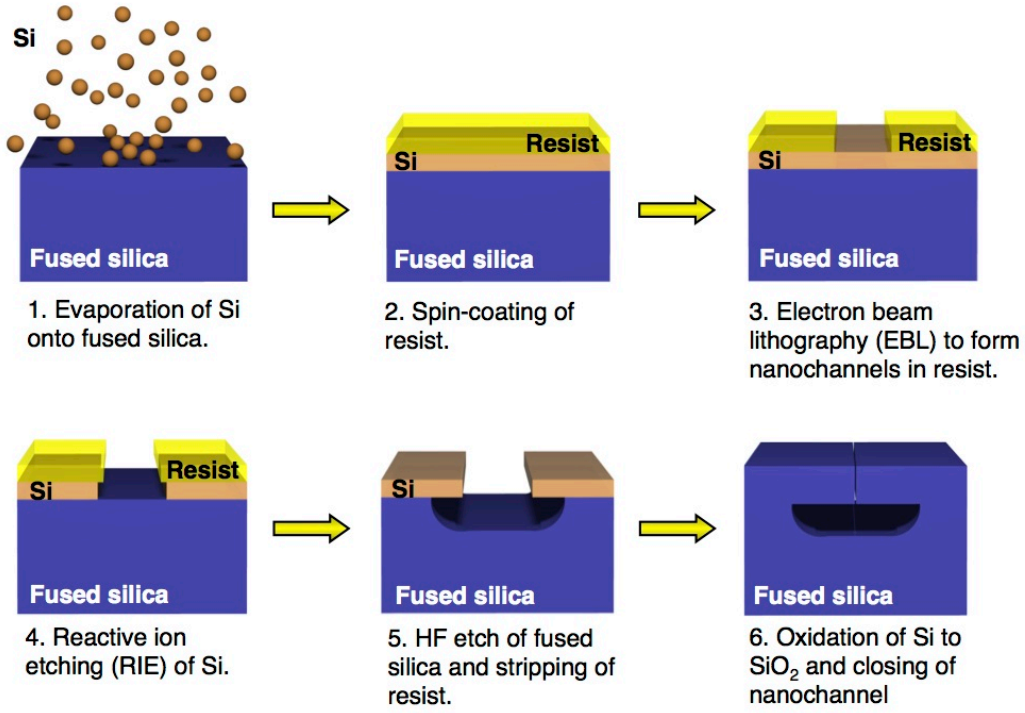

Figure 1: Schematic illustration of the fabrication process. The optimized process includes partial oxidation of the Si layer after step 1 and a two-step RIE to avoid lateral underetching of Si in step 4.

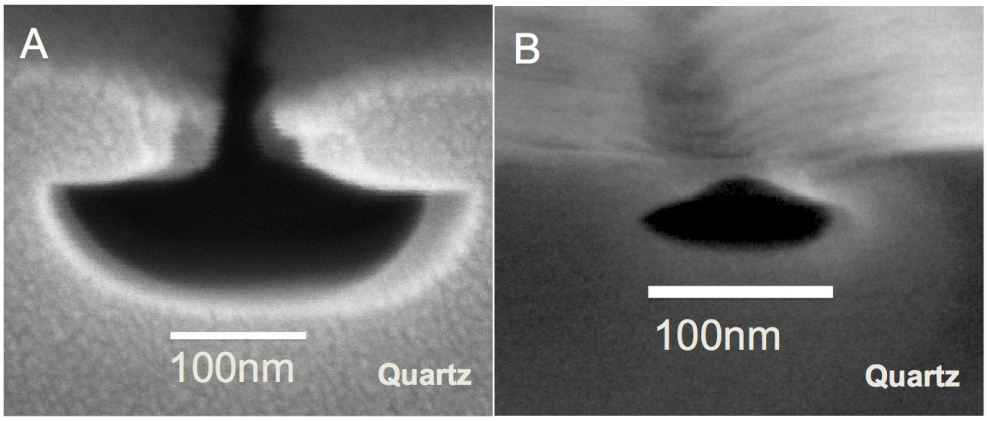

Figure 2: (A) Nanochannel on fused silica with 35 nm wide slit on top. Grainy structures on fused silica surface are due to sputtered Pt prior to SEM inspection. (B) Completely closed, 100 nm wide, subsurfaced nanochannel on fused silica.