Extra-long (1.5 cm), Single Nanofluidic Channel (Sub-30 nm wide) Fabricated by Novel Nanoimprint Mold Fabrication and Direct Imprinting of Functional Materials

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A single, long (cm length), smooth, and uniform-width nanofluidic channel is needed for stretching and detecting base-pairs in rapid analysis and sequencing of DNA. But they are extremely difficult to be made by conventional fabrication methods, such as electron beam lithography (EBL) and reactive ion etching (RIE), due to two challenges: (1) line edge roughness generated in EBL and RIE will clog a long nanochannel; (2) the difficulties in keeping an electron beam focused on a continuous line over cm distance (conventional EBL has only a ~100 um scanning range and is incapable to stitch the nanochannel; and the EBL with a fixed beam and scanning stage could not keep the beam in good focus over cm length).

To overcome these issues, we have proposed [1] and demonstrated a novel technology for making the single cm-long nanofluidic channel with ultra-smooth sidewalls, uniform channel width, and continuous fluidic channel by novel nanoimprint mold fabrication and direct imprinting of functional materials.

As shown in the schematic (Fig. 1), an imprint mold with single cm-long, uniform width, continuous fluidic channels is fabricated by (a) wet crystalline anisotropic etching of (110) silicon surface (using silicon-on-insulator wafer (SOI)), (b) conformal deposition of SiN_x by LPCVD, (c) CHF_3/O_2-based reactive ion etching (RIE) of SiN_x; and (d) removal of Si, forming a protrusive SiN_x line. The crystalline anisotropic etching removes the edge roughness, and the conformal deposition ensures a uniform and continuous channel regardless of the sidewall roughness. The final step of making the device is a direct imprinting of the mold in a functional material, which duplicates the smooth sidewall, uniform and continuous channel from the mold. This novel process either completely avoids the problematic EBL and RIE, or use RIE only once.

Fig. 2 shows a cross-sectional SEM image of a mold bearing a 25 nm wide 1.5 centimeter long protrusive nanochannel pattern. The smooth and vertical sidewalls of the mold are attributed to the nature of orientation-dependent wet chemical etching of (110) Si surface and conformal LPCVD of SiN_x.

The fabricated mold imprinted channel structures in various materials. Fig. 3 shows a single nanochannel directly imprinted into a Nanonex NXR-3020 UV-curable material layer (width: 26 ± 3 nm; length: 1.5 cm), which itself can be used as a nanofluidic channel. Four SEM images captured at different locations along the channel indicate that the standard variation of the channel width over a centimeter-scale length is within nanometer scale.

The long single channel structure in the functional material was used as an etching mask to faithfully transfer the patterns into other hard substrates (SiO_2) by a CF_4-based RIE, achieving a 30 nm wide single nanochannel (Fig. 4 (a)). The RIE did add an edge roughness of ~5 nm (Note: RIE should be avoided if the total channel width is ~10 nm).

After sealing the long nanochannel top with a transparent cover slip through quartz-quartz bonding, the continuous flow of fluorescent dye-contained DI water through the single long channel without clogging was observed (Fig.4 (b)).

The success in fabrication of the single, cm-long, uniform-width, continuous nanofluidic channel is a key step forward to the analysis of single DNA.

[1] S. Y. Chou, unpublished, **2005**.

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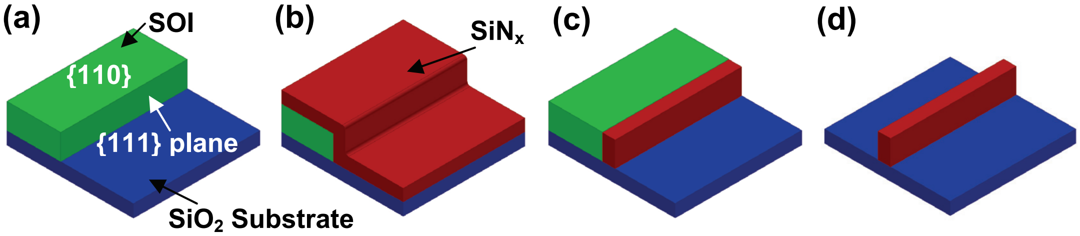

Fig. 1. Schematic of the fabrication for making an imprint mold having a single, cm-long, uniform-width, continuous nanochannel. (a) Anisotropic wet etch of Si (110) surface of SOI wafer; (b) conformal LPCVD of SiN_x; (c) CHF_3/O_2 RIE of SiN_x; (d) removal of (110) Si and formation of a protrusive mold.

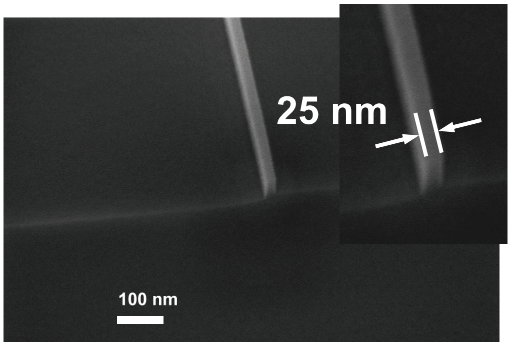

Fig. 2. The cross-sectional SEM images of an imprint mold having a 25 nm wide, smooth, uniform, 1.5-cm-long single nanochannel pattern (protrusive ridge).

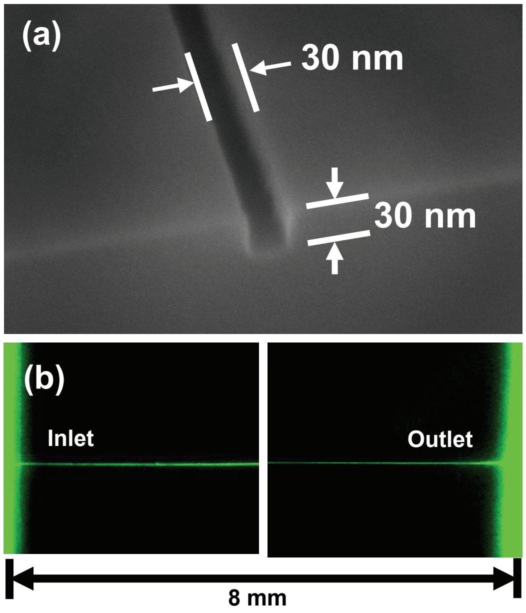

Fig. 4. (a) The cross-sectional SEM image of a 30 x 30 nm nanochannel transferred into a SiO_2 layer by CF_4/H_2 RIE. (b) Capillary flow with fluorescent dye into a 30 nm wide centimeter-long single nanochannel.

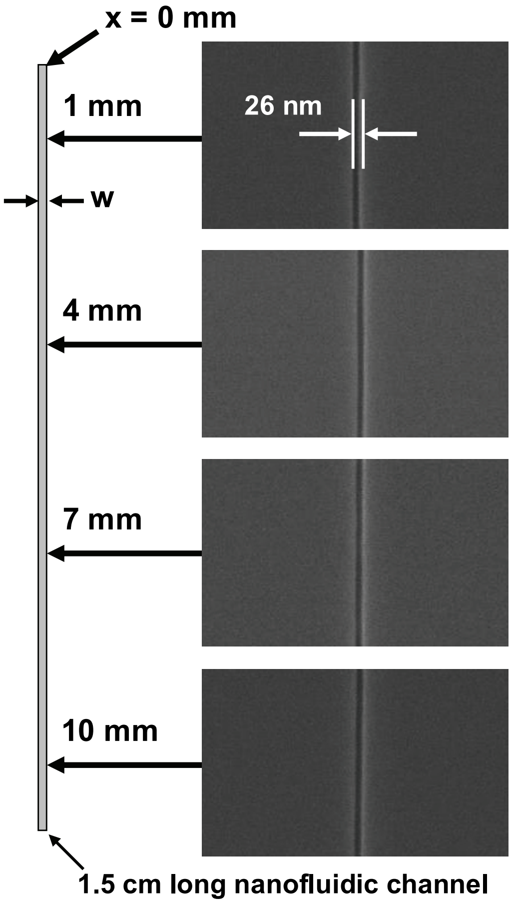

Fig. 3. A 1.5-cm-long, uniform-width, continuous nanochannel directly imprinted in a UV-curable material layer. Four SEM images captured at different locations along the channel show the great uniformity of the channel width over a centimeter length (w = 26 ± 3 nm).

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