# Selective Surface Energy Modification of SU-8 Nanochannels for DNA Analysis

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Surface energy plays an important role in fluidic systems, from determining the fluidic flow rate to immobilization of biomolecules such as DNA and proteins to the channel walls. In this paper, we demonstrate the selective modification of surface energy in micro- and nano-fluidic channels to immobilize stretched DNA molecules on SU-8 surfaces.

Figure 1 shows a cross-section of 200 nm wide SU-8 nanochannels sealed on a Si substrate using a 2-step reversal UV imprint. Nanochannels are first formed in SU-8 coated on glass by thermal imprint at 45 °C, 2 MPa, and 30 s UV exposure. The SU-8 channels are then transferred to a Si substrate with a 100 nm thick SU-8 adhesion layer. The reversal imprint is carried out in 2 steps, with first step at 45 °C, 2 MPa, and 30 s UV exposure and the second step at 55 °C, 2 MPa, and 2 s UV exposure. The imprint conditions ensure that the SU-8 channels are intact during the reversal imprint. 500 pg/μl of λ-DNA molecules in tris ethylene diamine tetraacetic acid (EDTA) buffer are immobilized and stretched inside SU-8 micro- and nano-channels as shown in Fig. 2. The 200 nm wide nanochannels in Fig. 2(a) are fabricated using the 2-step reversal UV imprint. The 10 μm half pitch SU-8 patterns in Fig. 2(b) are patterned on glass by photolithography followed by imprint to 100 μm wide and 1 μm deep Si microchannels at 80 °C and 3 MPa for 3 min. Without any surface treatment, the SU-8 surface is hydrophobic, resulting in the attachment of DNA molecules to SU-8 and they are stretched due to the fluid flow. In Fig. 2(b) there is no DNA attachment to the hydrophilic glass (dark region) compared to appreciable DNA attachment on the hydrophobic SU-8 patterns.

The variation of flow rate with channel width is shown in Fig. 3. This flow rate corresponds to the TRIS-EDTA buffer being pumped into the channels from the inlet due to evaporation from the outlet. Flow rate increases with narrower channel width because the volume of fluid reduces and capillary pressure increases in narrower channels.

Figure 4 shows coiled DNA molecules inside a 100 μm wide and 1 μm deep Si microchannel sealed with SU-8 as an adhesive. The SU-8 surface is exposed to an $O_2$ plasma at 80 W and 250 mTorr for 30 s before bonding to the Si microchannels at 80 °C and 3 MPa for 3 min. Since the SU-8 surface becomes hydrophilic after the $O_2$ plasma exposure, there is no DNA attachment to the SU-8 and hence there is no immobilized stretched DNA. The surface energy for SU-8 is increased from 30 to 70 mJ/m$^2$ after the $O_2$ plasma exposure.

Figure 5 shows the fabrication sequence of patterning hydrophobic and hydrophilic surfaces inside sealed channels. PMMA is first patterned on a hydrophilic surface (glass or oxidized Si). In a second step, SU-8 channels are sealed to the patterned Si substrate as shown in Fig. 5(c). A hydrophilic oxidized Si and a hydrophobic PMMA surface are integrated with SU-8 channels to form a sealed fluidic system with patterned areas at various surface energy.

Figure 6 shows a fluorescent micrograph of sealed 10 μm wide SU-8 channels (bright vertical lines) on a Si substrate with patterned PMMA structures running horizontally. The lower surface energy of polymers such as PMMA and SU-8 compared to Si can be used to immobilize DNA molecules inside sealed channels. It is easier for DNA to attach to the patterned SU-8 than to the Si channels. Figure 7 shows λ-DNA molecules immobilized and stretched across 6 μm wide SU-8 patterns sealed with Si microchannels that are 100 μm wide and 1 μm deep. In this case, the SU-8 has lower surface energy than Si, hence DNA molecules are attached and stretched across the SU-8 patterns.

In summary, we have demonstrated surface energy modification inside sealed channels by patterning polymer structures and exposing the polymer to an $O_2$ plasma. The sealed SU-8 channels are formed by reversal UV imprint. DNA stretching on SU-8 surfaces and across SU-8 structures inside sealed channels are demonstrated.

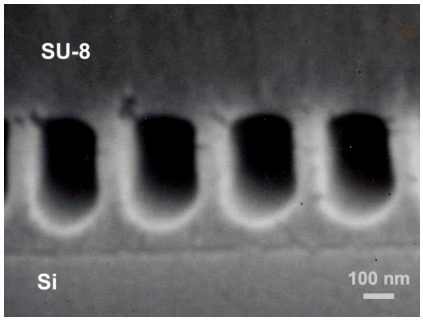


Fig. 1. 200 nm wide sealed SU-8 nanochannels fabricated by 2-step reversal UV imprint.

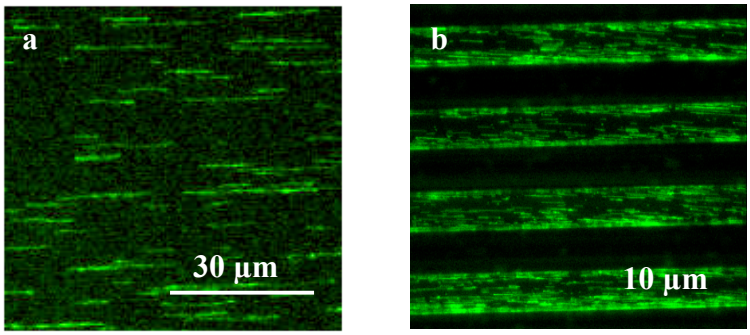


Fig. 2. λ-DNA molecules immobilized and stretched (a) 200 nm wide and (b) 10 µm wide SU-8 channels after the flow is stopped.

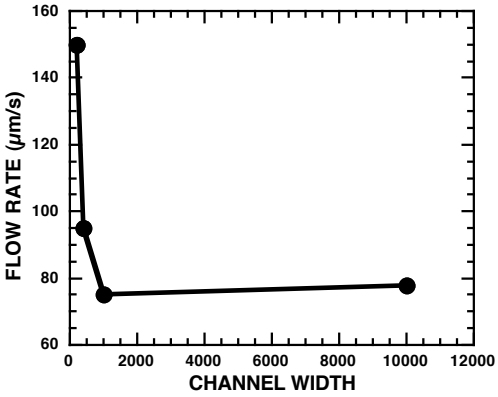


Fig. 3. Variation of flow rate with channel widths.

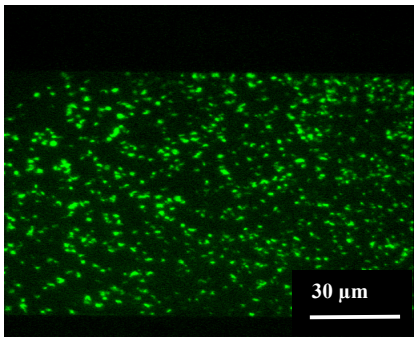


Fig. 4. No λ-DNA attachment on SU-8 after exposure to $O_2$ plasma. The flow in SU-8 channels is stopped.

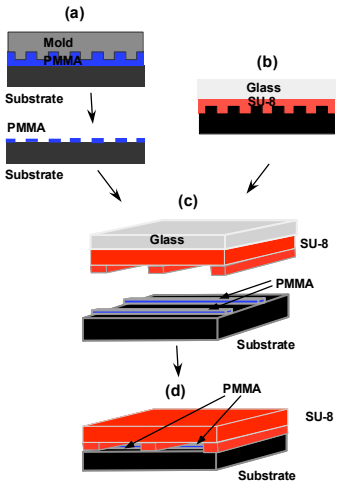


Fig. 5. Sealed SU-8 channel with PMMA patterns.

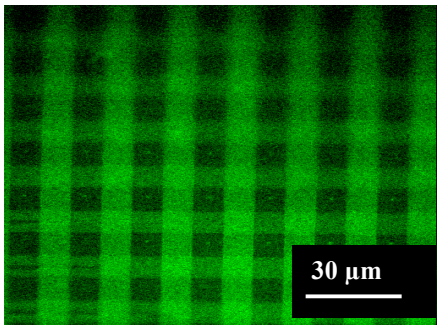


Fig. 6. Fluorescent micrograph of PMMA patterns on Si below SU-8 channels. Dark squares are Si, bright vertical lines are SU-8, and lighter horizontal lines are PMMA.

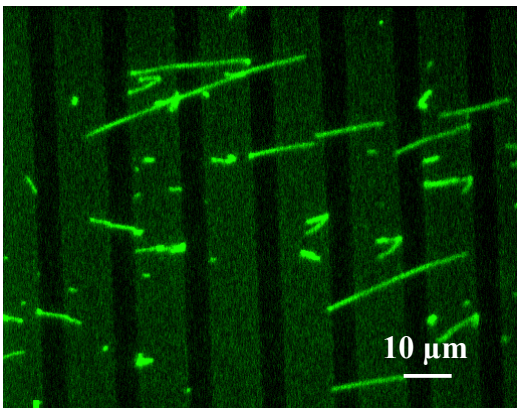


Fig. 7. λ-DNA molecules attached to and stretched across SU-8 patterns above Si channels after the flow is stopped.