Fabrication of Porous Nanochannels using Nanoparticles and Application to the Transport of DNA Molecules

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Enclosed micro- and nanochannels are of increasingly technological importance for the study of fluid behavior at the nanoscale, as nanofluidic devices, and for the detection and separation of biological species such as DNA [1]. Several techniques have been developed to fabricate nanochannels for biological detection and identification, including nanoimprint [2] and interferometric lithography [3]. However, a simple, yet facile, fabrication approach for nanochannel-based sensors remains a challenge. Here, we demonstrate a simple approach to the fabrication of enclosed nanochannels and explore the applications for transport of DNA as an example of applications.

Enclosed porous nanochannel structures including multiple layered channels were successfully fabricated using interferometric lithography, spin-coating driven self-assembly of silica nanoparticles and high temperature calcination (Fig. 1). A unique characteristic of these enclosed channels is the porous boundaries, which allow fluid flow across as well as along the channels.

We observed DNA transport in 1D porous nanochannel structures, using capillary action (hydrophilic surface tension) as the driving force (Fig. 2 and Fig. 3). Fig. 2a shows that the liquid (DI water with fluorescent dye) filled the 1D channels uniformly and continuously. Fluorescently stained (YOYO-1) DNA molecules (lambda-phage) were effectively transported into these porous channels forming elongated streaks (Fig. 2.b) with a length much larger than the known perimeter length of ~ 10 μm. The DNA transport in the channels rapidly and accumulate into bright line regions (Fig. 2.c and 2.d) showing a strong concentration enhancement. Furthermore, we can observe the motion of single DNA molecule in these channels using a diluted DNA buffer solution (Fig. 3). This system enables the transport, detection and separation of DNA molecules in porous nanochannels for single DNA assays.

References:

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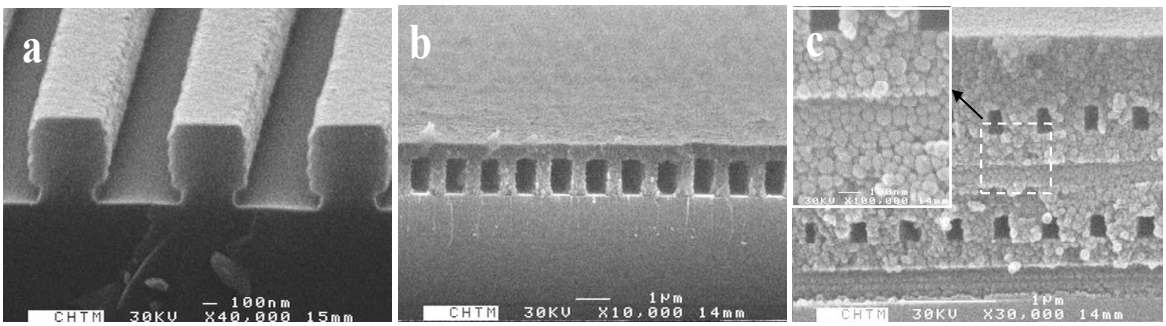

Fig. 1. 1D enclosed channels with silica particles**:** (a) PR pattens; (b) 1D channel with 50-nm silica nanoparticle; (c) multi-layered channels; inset: enlarged image of part of (c).

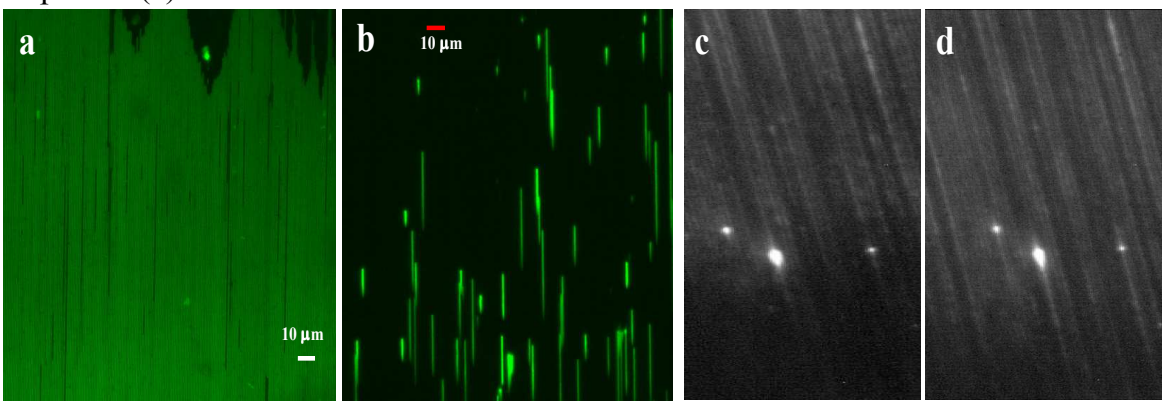

Fig. 2. Dye and DNA image in nanochannels (pitch: 1200 nm, channel: 600 X 600 nm^2): (a) fluorescent dye image with confocal microscope showing uniform filling; (b) confocal microscope image of Hind-III digested lambda DNA; (c)-(d) microscope image of DNA with 3 second interval showing concentration enhancement and "stacking" of the DNA at the up of the image. All image regions are far from injecting well. The fluidic flow is bottom to top of images.

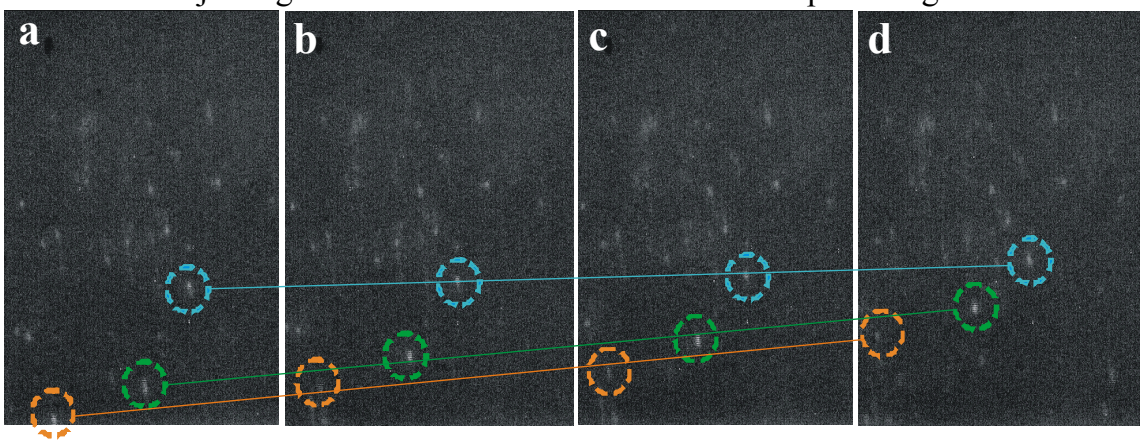

Fig. 3. Single DNA molecule transport in nanochannels with diluted DNA buffer solution, time interval: 0.15 s. Orange, green and blue circles track individual DNA molecules. The velocity is clearly inhomogeneous and consistent with the concentration enhancement (decreasing as the DNA moves further from the channel entrance.