Pneumatic Controlled Nano-Sieve Chip for the Capture of Nanocrystals

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The efficient isolation and retrieval of nanostructures and biomolecules are the key for numerous biomedical applications such as molecular diagnostics, precision therapeutics, and mechanobiology. Previously we developed a nano-sieve device that can efficiently capture microparticles by controlling the hydrodynamic deformation in a shallow and wide microchannel [1]. This nano-sieve device has been used for the capture of microorganisms from complicated biofluids [2-3]. However, when dealing with nanofeatures smaller than 100 nm, the capture efficiency significantly drops even at low flow rates. In this work, we present an improved nano-sieve system by including micro-grooves in the microchannel to enhance the target capture (**Figure 1a**). The micro-grooves were defined by stepper lithography, followed by a one-step wet etching process (**Figure 1b**). In addition, a two-layer PDMS based pneumatic chamber is integrated with the nano-sieve device (**Figure 1c**). With an applied positive air pressure (5 psi), the thin PDMS membrane deforms and reduces the hydrodynamic deformation caused by the liquid flow. We show that this system can efficiently capture low concentration CdSe quantum dots with a feature size of ~15 nm (**Figure 1d**). Furthermore, we developed a numerical model to understand the fluid field and target capture at various flow rates (**Figure 2a**). We show in the simulation that the fluid motion is dominated by the micro-grooves (**Figure 2b**). We found that the fluid motion is affected heavily in the entrance area (**Figure 2c**) and that a larger cutout depth (etching depth on micro-grooves) can reduce the fluid disturbance (**Figure 2d**).

References

[1] Chen, Xinye, Luke Falzon, Jie Zhang, Xiaohui Zhang, Ruo-Qian Wang, and Ke Du. "Experimental and theoretical study on the microparticle trapping and release in a deformable nano-sieve channel." Nanotechnology 31, no. 5 (2019): 05LT01.
[2] Chen, Xinye, Abbi Miller, Shengting Cao, Yu Gan, Jie Zhang, Qian He, Ruo-Qian Wang et al. "Rapid escherichia coli trapping and retrieval from bodily fluids via a three-dimensional bead-stacked nanodevice." ACS applied materials & interfaces 12, no. 7 (2020): 7888-7896.
[3] Chen, Xinye, Shuhuan Zhang, Yu Gan, Rui Liu, Ruo-Qian Wang, and Ke Du. "Understanding microbeads stacking in deformable Nano-Sieve for Efficient plasma separation and blood cell retrieval." Journal of Colloid and Interface Science 606 (2022): 1609-1616.

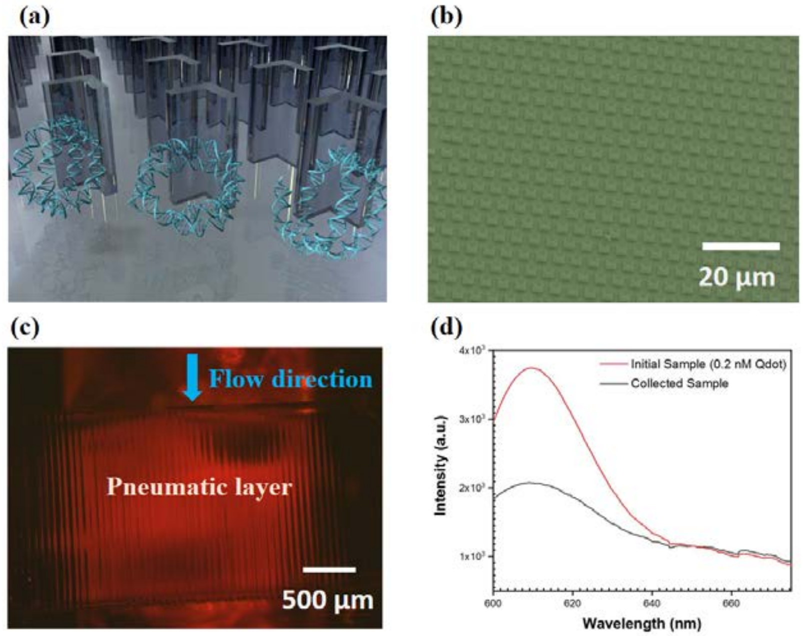

Figure 1. (a) Schematic of the micro-groove patterned nano-sieve for the capture of nanofeatures. (b) SEM image of the micro-grooves patterned on silicon dioxide. (c) Fluorescence microscope image of the nano-sieve channel, showing red fluorescence caused by the quantum dots. The pneumatic layer is bonded on top of the nano-sieve. (d) Fluorescence signal of original quantum dots (red) vs. collected sample (black), indicating that a large amount of the quantum dots is captured in the channel.

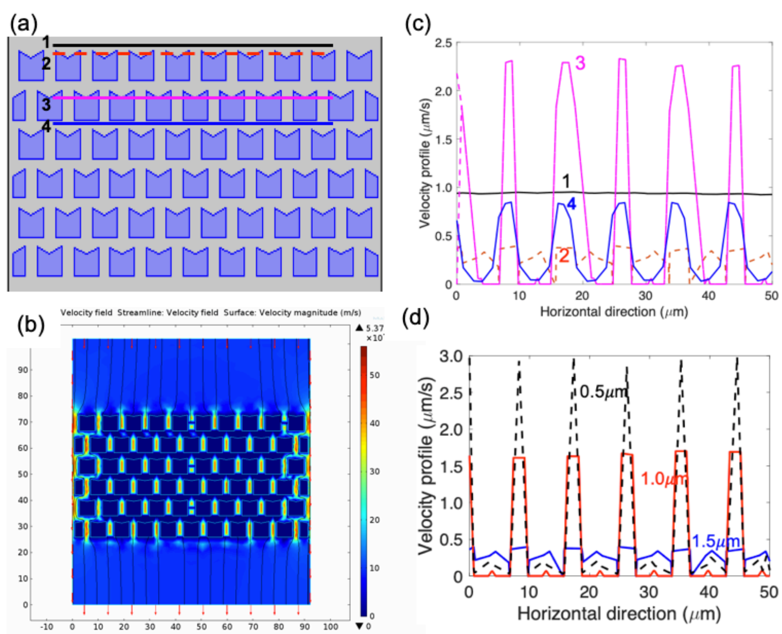

Figure 2. (a) Model of the micro-grooves as characterized in Figure 1b. (b) The contour of fluid velocity within the micro-grooves. (c) The fluid velocity distribution at different locations as indicated in Figure 2a (the four horizontal lines). (d) The fluid velocity distribution at Line 2 of three micro-groove structures with three different cutout depths (0.5 µm, 1.0 µm, 1.5 µm).