Nanofluidic channels as advanced molecular sieves: Continuous-flow DNA and protein separation

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Recent advances in fabrication techniques allows one to create regular nanofluidic pores and channels down to 15~20nm in critical dimension, with excellent uniformity and size control 1. This creates unique opportunities for molecular sieving, since now one can manufacture even a ‘membrane’ with regular pore shape, and the sizes which were only possible with random nanoporous materials such as gel and polymer monolith2,3. Such a massively parallel nanofluidic membrane would have many applications in molecular separation, photonics, and possibly any membrane applications.

We have recently created a fabrication strategy for building a massively-parallel nanochannel membrane structure, with a good pore size control down to ~30nm. (Figure 1) The fabrication technique only involves standard photolithography and MEMS fabrication techniques, and can be done on a wafer scale. This technique essentially solves the limited throughput of previous planar nanofluidic channels1, allowing the possibility of using regular MEMS-fabricated nanofluidic channels for various membrane applications. The effective pore density is comparable to that of nuclear track-etched membranes.

One of the important advantages of MEMS-fabricated nanofilter membranes is the flexibility of membrane system design, which is not readily achievable in random nanoporous materials. As an example of such engineering, a novel biomolecule (protein and DNA) separation device is presented in the talk. We have successfully designed and fabricated an anisotropic sieving structure that can be used for size separation of various biomolecules4. The sieving structure consists of a two-dimensional periodic array of nanofluidic filter (nanofilter). The bidirectional electrophoretic motion of biomolecules in the sieving structure causes molecules of different sizes to follow radically different paths, leading to efficient separation. Using this sieving structure, we have implemented a high-throughput, continuous-flow biomolecule separation device and evaluated its performance on various biologically relevant molecules. Our device can continuously size-fractionate a wide range of dsDNA fragments (50bp–23kbp) and protein complexes (11kDa–200kDa) in less than 1 min. It has to be recognized that the anisotropic sieving properties designed into the system is the key to the operation, and such an operation would not be readily possible with random, isotropic sieving matrix.

Given the unique advantages of nanochannel membranes, it is expected that massively parallel nanochannel membranes would find many applications in proteomics, sample preparation, ion selective membrane applications such as fuel cells.

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References


