Particulate-like Nanoporous Microdevices for Biomedical Applications

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A robust manufacturing protocol is proposed based on the selected integration of a number of micro- and nano-manufacturing modules to produce particulate-like polymer nanoporous microdevices (NMDs). At this stage, we have successfully developed techniques for fabricating a conically-shaped nanonozzle array, followed by reinforcing the nanochannels with silica. With these conically shaped nanonozzles, the electrokinetic transport of rigid particles and flexible DNA molecules was also studied in two important flows: converging flow and diverging flow.

A Sacrificial Template Imprinting (STI) approach was developed and applied to the fabrication of the polymer nanonozzle array with high convergence ratios. In this approach, a polymer sacrificial template, instead of the master, is used in the fabrication, which can be easily removed after molding and recycled. It avoids generating structural damage or defects during de-molding. A two-step replication was then applied to produce polymer sacrificial templates with a PDMS mold serving as the transition mold to generate inverted conical nanowells from the fiber-optic master by replica molding. Nanonozzles are formed by spin-coating a thin layer of polymer solution. As the result of meniscus, nanonozzles fabricated by this approach have a volcano shape with an aperture part less than 1 μm of the 3 μm total height. The channel diameter is 80 nm on the sharp end and the convergence ratio over 30. Nanonozzles with various convergence ratios can also be obtained. To further precisely tune the channel size as well as enhance their mechanical strength and dimensional stability, a dynamic assembly approach is combined by growing silica on the internal surface of nanonozzles. This was realized via external force-induced dynamic surface reactions. Electro-osmotic flow (EOF) was used to drive molecules or their precursors into the nanonozzles and surface chemistry was used to control the growth of nanostructures on the channel wall. As a demonstration, the nanonozzle size at the sharp end was successfully reduced from 200 nm to 50 nm.

These polymer nanonozzles with uniform conical fluidic channels can provide two important flow patterns: converging and diverging flow. Both can fulfill the requirement of good sieving efficiency as well as high transport rate, which cannot be accomplished simultaneously using commercial sieving products. Different electrokinetic transport behaviors were observed with rigid colloids nanospheres and flexible polymers (i.e., DNA). Rigid nanospheres rapidly stacked in the converging flow, while they experienced hindered transport in the diverging flow. Nearly 100% were retained when the nanosphere size was equal to the channel size. In contrast, the converging flow can moderately stretch flexible polymers (i.e., DNA) to achieve easy pass, even when the equilibrium size of molecules is much larger than the channel size. The tapered channels produce a great velocity gradient over a short distance, providing sufficient forces to ensure stretching of the DNA along the 3μm travel distance of the nanonozzles.

Reference:

[1] For further information about this project, email lee.31@osu.edu