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Effects of Nanostructured Surfaces on Electro-osmotic Flow

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Electro-osmotic flow (EOF) is the flow of fluid in a microchannel which is induced by an external electric field. EOF originates from electrical double layer (EDL) formed spontaneously at the channel-fluid interface. The electrostatic potential at the channel wall is called the zeta potential. Nanostructures have been employed in microfluidic channels for electrophoretic separation of biomolecules [1] and catalytic reaction which yields higher reaction efficiency due to the increased surface area [2]. However, the effect of nanostructured surfaces on EOF has yet to be fully understood. In this preliminary investigation, we demonstrate experimentally that the presence of nanostructured surfaces affects EOF significantly.

Microchannels (cross section of 3.9/6.5/33µm x 100µm and length of 5cm) with nanostructures on the bottom wall were fabricated by a series of steps that can be divided into three phases; fabrication of the master structures on a silicon (Si) wafer, creating of mold insert via electroplating and injection molding with Cyclic Olefin Copolymer (COC). The two types of nanostructures employed in our investigation are prolate hemispheroid-like structures (diameter of 130-370nm, height of 100-420nm and spatial distance of 160-560nm) and indented lines (period of 330nm, line width of 180nm and height of 170nm) which are perpendicular or parallel to the EOF direction. Current monitoring experiments were conducted to study the effects of these nanostructured surfaces on EOF behavior.

Zeta potential is an important parameter that dictates the direction and velocity of EOF. The zeta potentials of 1mM sodium bicarbonate ($NaHCO_3$) in microchannels with different nanostructured surfaces were measured with current monitoring method and shown in Fig. 1, and compared to a smooth microchannel. For prolate hemispheroid-like structures, the magnitude of zeta potential is reduced by ~10%. The reduction in the magnitude of zeta potential for perpendicular indented lines is even larger (~30%). However, no significant difference is observed for the case of parallel indented lines. These results reveal that EOF velocity is lowered by the introduction of nanostructured surfaces in certain orientations. EOF originates from the interaction between EDL (nanometer thickness) and the applied electric field. The presence of nanostructures distorts the local electric field at the wall and thus affecting the overall flow velocity.

Precise control of fluid flow is critical in microfluidic lab-on-a-chip devices. Our investigation contributes to the fundamental understanding of EOF behavior in devices which utilize nanostructured surfaces for chemical and biological analyses.

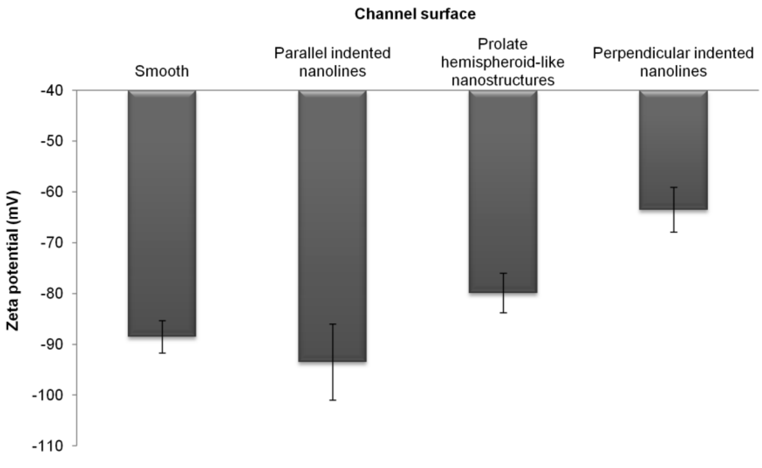

Figure 1: Zeta potential of 1mM sodium bicarbonate ($NaHCO_3$) for microchannels with different nanostructured surfaces, in comparison to smooth microchannel.

References

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