Traveling-Wave Electro-osmosis of Water above Microelectrodes

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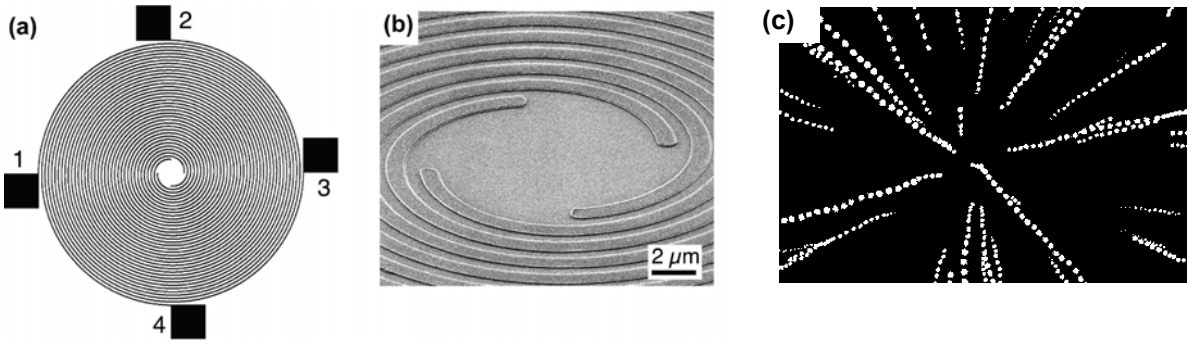
We report ac electro-osmotic flow in aqueous electrolytes on application of a traveling-wave electrical field to a micro-electrode structure. This structure takes the form of four aluminium electrodes arranged in a spiral and was manufactured by electron-beam lithography and subsequently coated with a thin polymer film. A purpose-built four-phase voltage supply generates square-wave-form traveling-wave signals in the range between 10 kHz and 5 MHz. These signals were applied to the four electrodes so that there was a 90° phase difference between neighbouring electrodes. We provide experimental evidence that streaming takes place on application of a traveling wave of potential by tracing the movements of fluorescent latex beads over a spiral electrode structure. Streaming takes place within a couple of micrometers of the electrode surface. Velocities up to 200 μm/s were observed for low applied potentials, amplitudes of less than 0.5 V. We explain the phenomenon by deriving an analytic solution of the electrokinetic equations leading to an expression for the slip velocity of electro-osmotic flow as a function of the amplitude of the applied electrical potential, the signal frequency, and the material properties of the system. For traveling-wave signals at frequencies of the order of the double layer relaxation frequency, the formation of the electric double layer lags the traveling-wave electric field and fluid flow in the direction of the traveling wave can take place.



Figures (a) Schematic drawing of the spiral electrode structure, four electrodes are arranged in a spiral structure and numbered 1-4. (b) Scanning electron microscope image of the centre of the spiral electrode structure. (c) Superposition of thresholded images showing fluorescent bead movement over the spiral electrode structure