

Fast Three-Dimensional Electrokinetic Pumps for Microfluidics

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Electrokinetic pumps are attractive for portable and flexible microfluidic analysis systems, since they operate without moving parts using low (battery-powered) alternating potentials. Since the discovery of AC electro-osmosis (ACEO) in the late 1990s, there has been much work in designing planar, periodic pumps, which exploit broken symmetry in electrode spacing and width to produce a streaming flow over a surface. Although surface-height modulation has been suggested as another means of breaking symmetry[1], it has never been numerically or experimentally pursued.

Recently, Bazant and Squires described more general flows due to induced charge electro-osmosis (ICEO) around three-dimensional metal structures[2], which has since been experimentally realized in microfluidic systems[3]. Motivated by ICEO around raised electrodes, we are developing a variety of new three-dimensional AC electrokinetic pumps capable of much faster directional flows than planar ACEO pumps (for the same applied voltage and minimum feature size) by an order of magnitude according to the usual low-voltage model. This phenomena and an example microfabricated device are illustrated in Figure 1. We test and improve our theoretical designs experimentally in a microfluidic loop[4], as shown in Figure 2. Our pumps involve interdigitated planar electrodes with raised metal structures from a simple electroplating step, which leads to greatly enhanced pumping.

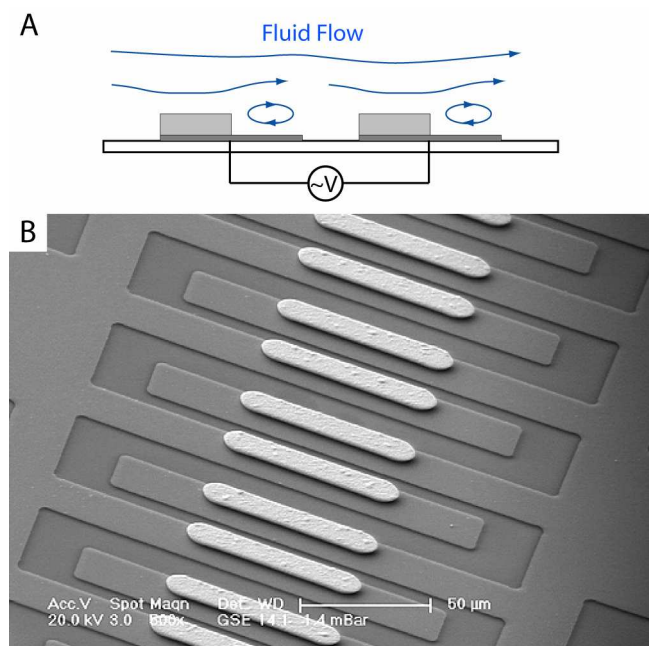


Figure 1: (A) Schematic diagram of fluid flow that may be generated by an AC field between two electrodes located on a substrate. This “Fluid Conveyor Belt,” containing partially raised electrodes, exploits naturally occurring fluid rolls to pump fluid in microchannels with voltages $< \sim 10$ V. (B) Electroplating is used to create the raised geometry on repeated periods of planar patterned electrodes.

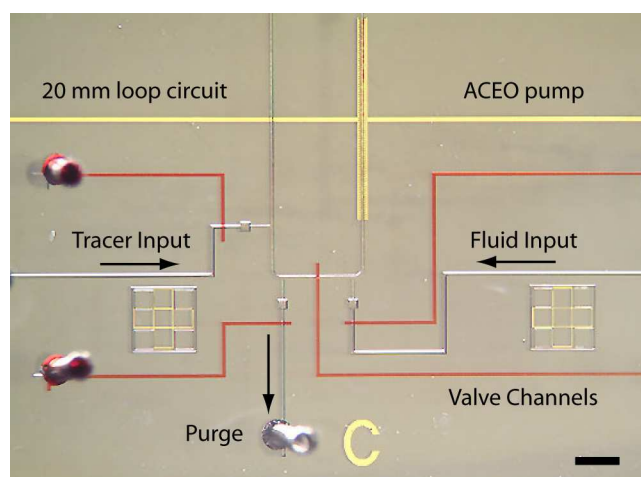


Figure 2: A microfluidic device featuring a closed loop channel is used to test AC electrokinetic pump designs. The PDMS chip, which caps the electrodes, provides fluid inputs and outputs, and isolates the working pump from external pressure perturbations. This approach enables systematic characterization of pump performance as a function of input voltage and frequency. The scale bar indicates 1 mm.

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