ELECTROOSMOTICALLY INDUCED HYDRAULIC PUMPING ON MICROCHIPS

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Abstract

We report the design and testing of microchips with salt-bridge junctions that were capable of inducing hydraulic pumping electroosmotically. The salt-bridge junction was a thin gap or channel (< 100 nm deep) connecting two closely spaced microchannels. When an electric potential was applied across the junction, the electroosmotic flow was lower in the thin channel relative to the microchannels. This generates a pressure at the junction that in turn produces hydraulic flow.

Keywords: electroosmotically induced hydraulic pumping, salt-bridge junction

1. Introduction

The ability to control the electric potential at any point within a microfabricated fluidic network enhances the operability of the device. An early approach was to use thin metal films for electrical contacts, but due to electrolysis, bubbles were generated at the electrode and in turn disconnected the electrode from the buffer solutions. We are investigating several techniques for forming intrachannel electrical connections that circumvent electrolysis issues. These salt-bridge junctions conduct electrical current by small ion transport but minimize or inhibit bulk fluid transport. In this paper, hydraulic pumping in the field-free channel was induced electroosmotically by applying a potential between the side 1 and waste 2 reservoirs and across the salt-bridge junction (Figure 1).

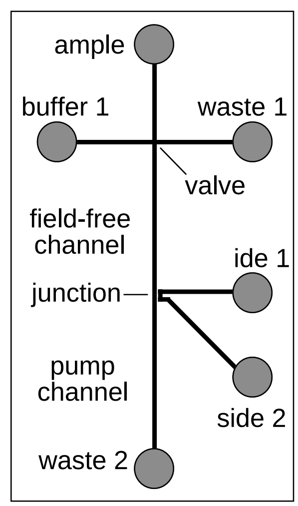

Figure 1. Schematic of microchip with a salt-bridge junction.

2. Experimental

For the microchip in Figure 1, the side 1 and pump channels were fabricated in close proximity to each other. For example, the initial spacing between these channels on the photomask was 25 µm. If the channels were etched 11 µm deep, the distance between the tops of the channels was 3 µm due to isotropic etching of the substrate (Figure 2). This distance is referred to as the length of the salt-bridge junction. The cover plate was then thermally bonded to the substrate at 500˚C. Due to incomplete bonding over short distances, e.g. 3 µm, a thin gap or channel exists between the side 1 and pump channels and the cover plate. This junction allowed electric current to pass but exhibited reduced electro-osmotic flow relative to the microchannels. If electrical conduction across the junction was not observed, a high potential, e.g., 8 kV, was applied between the side 1 and waste 2 reservoirs to break down the bonded region.

3. Results and Discussion

Figure 2 shows a fluorescence image of fluid flow at the junction with a potential applied between the side 1 and waste 2 reservoirs. The electro-osmotic flow in the pump channel was greater than the electroosmotic flow across the junction. Consequently, a negative pressure was generated at the junction, and sample was drawn from the field-free channel into the pump channel. This can be seen in Figure 2 where the left side of the pump channel was filled with a fluorescent dye (bright) and right side was filled with buffer (dark). By drawing a front of fluorescent dye through the field-free and pump channels, the pumping velocities were measured (Figure 3). The ratios of the flow rates in the field-free and pump channels (pumping efficiency) were 0.43 and 0.63 for the 1 and 3 µm wide bridges, respectively.

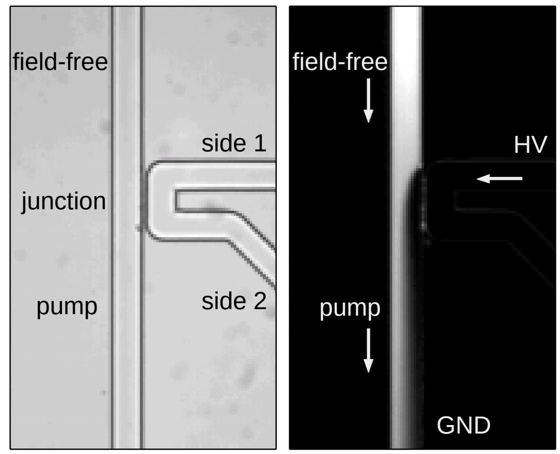

Figure 2. White light image of salt-bridge junction and fluorescence image of flow at junction. Side 1 reservoir is maintained at 2 kV (HV) and waste 2 reservoir is grounded (GND). Arrows depict direction of flow.

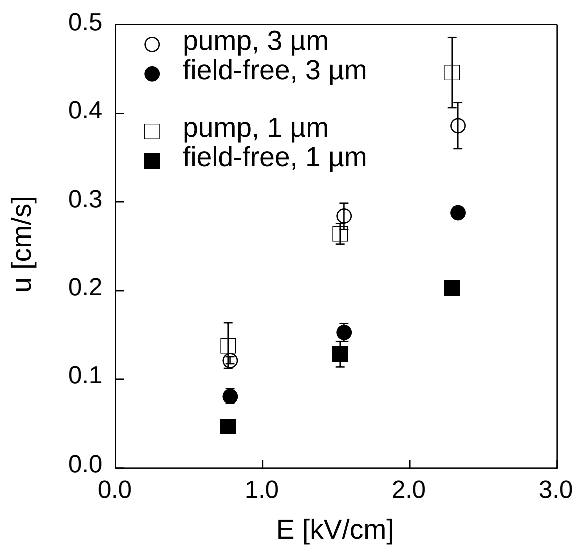

Figure 3. Variation of velocity (u) with field strength (E) in the pump and field-free channels for 1 and 3 µm wide junctions.

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