Improved Two-Side AC Electroosmotic Micropump

Luca Ribetto[1*], Alexandra Homsy[1]
and Nico F. de Rooij[1]

[1]Ecole Polytechnique Fédérale de Lausanne (EPFL), Institut of Microengineering (IMT), Sensors Actuators and Microsystems Laboratory (SAMLAB), Neuchâtel, Switzerland

This paper reports on the fabrication and experimental characterisation of improved design AC eletroosmotic micropumps. Since the first study and analysis of AC electroosmosis by Ramos et al. [1], many devices have been fabricated and tested [2]. The basic planar electrode design was improved and increased pumping velocities were measured. Among the proposed improvements, 3D electrode design seems very promising [3,4]. Nevertheless, 3D electrode structures occupy a large portion of the channel cross section, thus potentially reducing the generated flow rate. We demonstrate here that the flow generation may be improved, with no impact on the available cross-section, by using the planar electrode design to generate velocity on two sides of the channel.

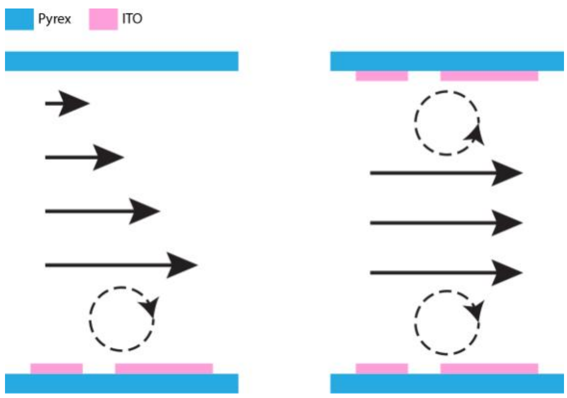

Figure 1 - Generated velocity profile for 1-side (left) and 2-side (right) prototypes. With electrodes on both sides of the channel, the velocity profile is expected to be flat in the middle.

In the basic planar electrode design, velocity is generated on one side of the channel and a Couette-like flow is induced in the bulk of the fluid, with the velocity going down to 0 on the opposite wall. The generated velocity on the electrode surface increases as the square of the applied voltage and has a peak frequency that depends on the geometry of the device [5].

In this work, the planar asymmetric electrode design is replicated on the roof of the pumping channel. This way, the pumping force is generated on two sides of the channel instead of only one. The generated flow pattern is no more Couette-like and the average flow rate is increased, thanks to positive velocity being generated on both the bottom and the top of the channel.

Table 1 - Relevant dimensions of the fabricated devices.

Channel depth	Channel width	Large electrode	Gap	Small electrode
100 µm	100 µm	25 µm	10 µm	15 µm

Figure 1 shows a schematic view of the expected generated velocity profiles along the flow direction for the 1-side- and 2-side-electrode prototypes.

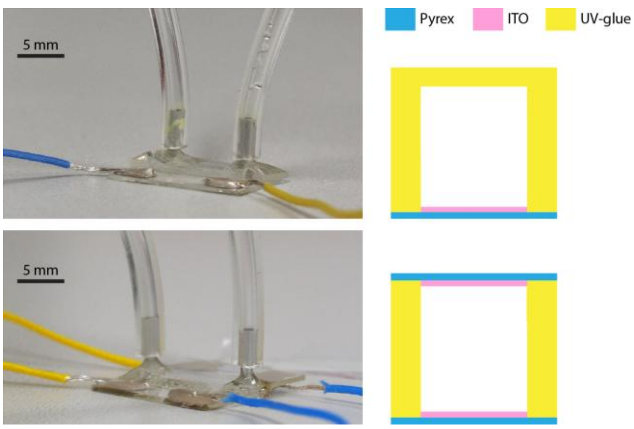

Figure 2 - AC EO micropump prototypes with electrodes on one side (top) and on two sides (bottom). A schematic view of the channel cross section is given on the right-hand side.

Prototypes were fabricated by sandwiching channels moulded in UV-glue [6] between two glass wafers, on which ITO electrode patterns had previously been defined by lift-off. Table 1 summarises the relevant dimensions of the fabricated devices, which are shown in Fig. 2.

The devices were characterised with 0.01 mM KCl buffer solutions. Micro beads (Molecular Probes, carboxylate modified, 1-2 µm diameter) were used to track the liquid motion. The generated velocity was extracted by particle image velocimetry (µPIV), using the MatPIV toolbox for Matlab. For each frequency and voltage, the generated velocity is evaluated as the average of the maximum observed velocities in each µPIV frame.

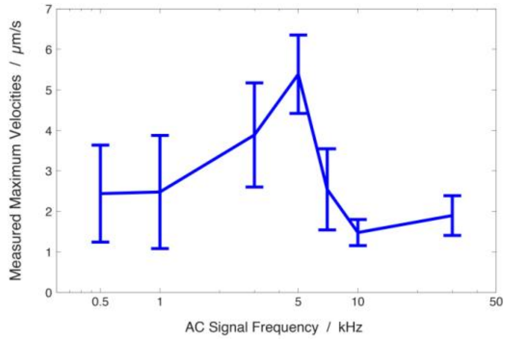

Figure 3 – Measured fluid velocities for the 1-side prototypes as a function of the frequency of the applied AC signal at 5 Vpp. The given values are obtained as the average of the maximum observed velocity in each µPIV frame. The graph shows an optimal pumping frequency, as expected from theory [5].

The velocities for the 1-side prototypes are plotted versus the frequency of the AC signal in Fig. 3. This allows identifying the optimal 5 kHz pumping frequency, which was used in subsequent experiments. Figure 4 gives the dependence of the generated velocity on the applied voltage. Both curves are in good agreement with theory [5].

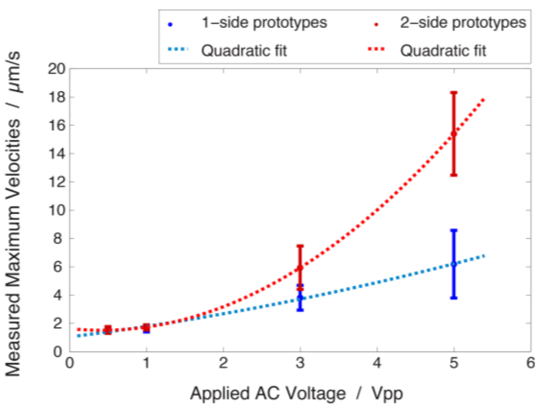

Figure 4 - Comparison of the measured velocities for the 1-side (blue) and 2-side (red) prototypes as a function of the magnitude of the applied AC signal at 5 kHz. The given values are obtained as the average of the maximum observed velocity in each µPIV frame. The dashed lines show that the experimental data depend on the square of the applied voltage, as expected from theory [5].

Experimental results are encouraging and show an increase of up to about 150% of the measured velocity in the 2-side pumps, compared to the simple one-side planar electrode design.

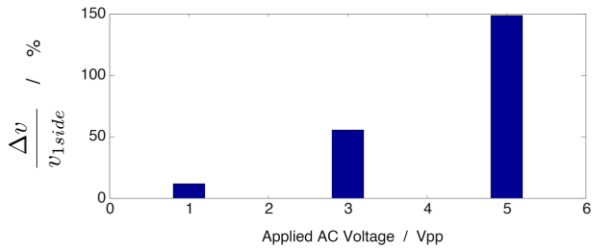

Figure 5 – Pumping velocity improvement in the 2-side devices, compared to 1-side prototypes, for the different tested voltages, calculated from the data plotted in Fig. 4.

The setup of alternative methods to characterise the generated velocity and confirm our results is ongoing. Future work will include the characterisation of the devices with KCl and phosphate buffers at different concentrations.

Keywords: valveless micropump, electroosmosis, AC electric field, MEMS.

This work has been supported by Tronics Microsystems S.A., Crolles, France.

References

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