P13: Electrokinetic based energy generation within micro-channels

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Introduction. Electrokinetic phenomena associated with fluid flow in micro-channels have been studied for different applications [1,2]. For example, electro-osmotic flow pumps involve driving a fluid along a narrow channel by applying an electric field along the length of the channel. This process is reversible, thus it is possible to use for electric energy generation where driving an electrolyte fluid along a narrow channel by a pressure difference at both side of the channel results in an electric potential along the length of the channel. Such electric potential can then be harnessed to drive an electric current through an external load [3]. Theoretical conversion efficiencies of up to 12% have been estimated [4], and experiments have claimed 3% efficiency using flat 75 nm microfabricated channels on silicon [5].

Experimental. Experimental investigations of microfluidic electrokinetic energy generation were initially undertaken using porous glass filters. More recently, single micro-fabricated channels or multiple micro-fabricated channel arrays have also begun to be used in experiments, which allow a more precise definition of the channel sizes and properties. We have investigated the performance of both types of systems, and simplified their fabrication. The devices described below are approximately 20 mm in length or in diameter, and were tested using 10^{-6} [M] solution of KCl as electrolyte.

Results and discussion. Our first system was made by stacking thin 15 μm thin sheets of PET, using 0.5 and 2 μm PET beads dispersed between the sheets as spacers. This allowed the formation of thin channels between the sheets, which were then encapsulated in glass with AgCl wire electrodes on both sides. We then investigated the performance of a single 500 nm glass channel, using Pt wire electrodes. A smooth flow-through system was also fabricated by placing small amounts of PET beads in the corners of the two sheets of glass making the channel, rather than dispersing the PET beads on the whole surface, which improved performance two fold. The greatest improvement of performance was achieved by increasing electrode surface area; this was done by sputtering a thin metal layer directly on the channel walls. Alumina porous filters were also tested as an off-the-shelf microfluidic system, with a thickness of 60 μm and a pore/channel size of 200 nm. Electrodes were fabricated directly on both sides of the porous filters by sputtering.

Table 1. Experimental results

Channels number, size and type	Material	Electrodes	ΔP (Pa)	Q ($m^3/s \times 10^{-9}$)	Rint (MΩ)	V (mV)	Pout (nW)	Efficiency Pout/(Q.ΔP) (%)
80 x 2 µm	PET	AgCl wire	14121	49.14	5	26.2	0.137	0.019×10^{-3}
80 x 500 nm	PET	AgCl wire	85115	19.4	0.8	84.1	8.84	0.613×10^{-3}
1 x 500 nm	Glass	Pt wire	99117	0.0356	10	34.2	0.117	3.330×10^{-3}
1 x 500 nm (smooth)	Glass	Pt wire	93183	0.1263	10	84.5	0.714	6.060×10^{-3}
200 nm porous filler	Alumina	Ag wire	36702	23	1.2	166	23	2.700×10^{-3}
200 nm porous filler	Alumina	Ag sputtered	36702	100	0.02	80	320	8.700×10^{-3}
1 x 500 nm (smooth)	Glass	Ag sputtered	74000	0.1309	10	120	1.44	18.000×10^{-3}

Conclusions. Our results (Table 1) suggest that that the disparity between the theoretical efficiencies for the systems we have fabricated (~1%) and the observed efficiencies would be bridged by decreasing channel sizes and by increasing further the electrode surface areas, possibly by using a conductive porous material for electrodes.

References

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