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RESEARCH PAPER

# Streaming currents in microfluidics with integrated polarizable electrodes

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**Abstract** A surface in contact with an aqueous solution is electrically characterized by the zeta potential. One way of determining indirectly the zeta potential of a surface is by measuring the streaming currents generated by a Poiseuille flow through a capillary channel with charged walls. We report measurements of streaming current in individual rectangular glass/PDMS microchannels with integrated miniaturized electrodes. Experiments performed using solutions with different salt concentrations and different electrode materials showed that the measured electrical current depends on the electrode material and in general differs from the real value of the streaming current. To determine the streaming current from the experimental data, an equivalent circuit model is proposed. The extracted value of the streaming current is proportional to the flow rate of electrolyte and the calculated glass/PDMS zeta potential scales linearly with the logarithm of the salt concentration. This work offers a thorough analysis of the effects that come into play during streaming current measurements and, in particular, it describes potential sources of error that can affect the streaming current measurements and suggestions on how to correct the measured values.

**Keywords** Streaming current · Polarizable electrodes · Microfluidics · Electrical double layer · Equivalent electrical circuit model

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## 1 Introduction

In a microfluidic channel, an electrical current resulting from the convective transport of ionic charges in the electrical double layer (EDL) is referred to as the streaming current. Measurement of the streaming current is a sensitive method to characterize interfacial electrical properties, such as the zeta potential or the surface charge density, of the microchannel walls (Delgado et al. 2005). Besides providing information about the interfaces of bare microfluidic substrates materials, like glass, silicon (Kirby and Hasselbrink 2004a), and polymers (Kirby and Hasselbrink 2004b), the analysis of the interfacial electrical properties has also been exploited to achieve label-free detection of DNA immobilization (Ueda et al. 2002) and hybridization (Martins et al. 2011). Another streaming current application worth mentioning, despite the low efficiencies so far demonstrated, is in the conversion of mechanical to electrical energy (Duffin and Saykally 2008; Olthuis et al. 2005; van der Heyden et al. 2007).

Streaming currents, produced by mechanically induced fluid flow in a microchannel, can be measured via two electrodes placed at each end of the microchannel (Delgado et al. 2005). Ideally, the measured current drawn through this low resistance external electrical circuit connecting the electrodes should be equal to the streaming current. Models that describe the streaming currents in microfluidics have been presented in literature; however, they focus on the electrokinetic phenomenon while neglecting sensing elements in the external circuit such as the influence of the electrodes (Chang and Yang 2010; Daiguji et al. 2004; Mansouri et al. 2007; Renaud et al.