On the cooperative role of DC electric and magnetic fields in micro-stirring

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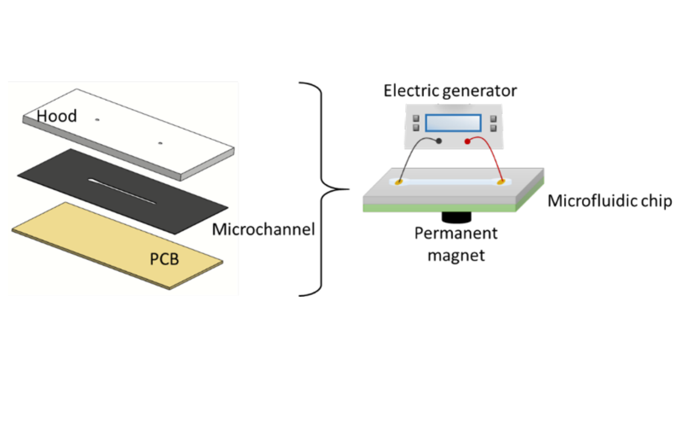
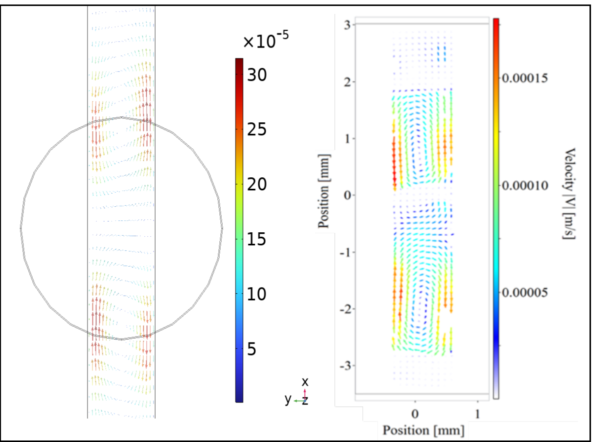
Effective stirring at microscale remains a challenge despite the need for enhancing molecular transport in biological microsystems. In this paper, a method is proposed to generate controlled micro-stirring by exploiting the respective assets of a uniform DC electric field and a non-uniform static magnetic induction. When an electric field is applied all along a microchannel filled with a ionic liquid buffer, an electroosmotic flow arises when the Debye thickness of the electric double layers along the walls remains smaller than the transverse size of the channel. Because an axial electric field acts on the non-uniform space charge across the EDL, a Coulombic force is generated that generates a liquid plug motion under viscous shear. We present comprehensive numerical simulations of such an electroosmotic flow that is modified by the local presence of a permanent magnet located beneath the bottom wall of a microchannel. This configuration allows for the exploration of magneto-electro-osmotic-induced micro-stirring. A companion experimental device (fig. a) is developed with a microchannel equipped with a permanent magnet. The latter introduces a non-uniform magnetic field that, in combination with the axial electric field, generates low magnetic Reynolds number vortices (fig. b). Such patterns are relevant for micro-stirring applications requiring stirring or collection of biological targets. Fluorescent microparticle image velocimetry (μPIV) confirms their presence within the microchannel. The vortices are driven by a spatially varying Lorentz force, the curl of the latter being identified as the mechanism responsible for micro-stirring so observed. This work provides a basic understanding of how controlled electric and magnetohydrodynamic forces can be harnessed to achieve efficient mixing at microscale, offering new avenues for applications in microfluidic systems, biological transport and detection.



(a) Device to promote a magneto-electroosmotic channel flow.



(b) Velocity fields obtained from numerical simulations (left) and Particle Image Velocimetry (PIV) (right) under a voltage of 20 V, with a 3mm-sized cylindrical magnet located just beneath the microchannel.