ABSTRACT

In this thesis, we have addressed several yet-to-be resolved issues pertinent to streaming potential mediated flows in narrow confinements. We first present the common picture that is routinely invoked in the literature for assessing the streaming potential established in a pressure-gradient driven flow based on electrical double layer effects. We then adapt this framework with appropriate modifications to study the influence of streaming potential in concert with other physical effects on the flow fields and on certain key characterizing facets of the pertinent system.

We investigate the combined influence of streaming potential and substrate compliance in the context of two technologically relevant physical set-ups: first, a nanorheometer geometry where a squeeze-flow is established in the intervening gap between a rigid sphere oscillating and an elastic substrate; second, a planar slider bearing where one of the walls is again made of a compliant material. We show that in both cases, the force response is modified by the streaming potential effects and that the effective stiffness strongly determines this influence. We next study the role of streaming potential as a modulator of volumetric flow rates in combined pressure-gradient driven and electroosmotic pulsating flows. Following a similar model, we also study the influence of streaming potential on pulsating flows through an annular geometry, highlighting the manifestation of asymmetric velocity profiles. In another investigation, we study the hydrophobic effects, captured using a phase-field model, in conjunction with streaming potential effects. We show that the effective electroviscous effects are determined through a sensitive interplay between the hydrophobicity mediated depletion length scale and the electrical double layer screening length. Finally, we correct a fundamental theoretical inconsistency in the traditional modelling framework of streaming potential mediated flows by establishing a link between the diffusivity and the steric factor, and highlight certain non-intuitive implications of this.

The conclusions and inferences drawn in the present thesis can be of immense consequence towards developing novel lab-on-a-chip applications, in general, and miniaturized electrokinetic energy conversion devices, in particular.

Keywords: electrokinetics, streaming potential, substrate compliance, pulsating flows, hydrophobicity, steric effects