ABSTRACT

In this dissertation we address several issues pertaining to electrokinetic flows over charge modulated surfaces in narrow confinements. We first develop a general formulation concerning electrokinetic flows in small scales and subsequently point to various fundamental limits, which help us simplify the governing equations. We then adapt this general formulation in conjunction with the appropriate limits in an effort to study electroosmosis and related phenomena over charge modulated surfaces, under different forcing conditions.

We first focus on "*Anisotropy in Streaming Potential*", wherein asymptotic solutions to streaming potential are obtained, in presence of anisotropic modulations in surface potential and surface wettability, represented in terms of equivalent Navier slip length. We show that modulations in slip length can both augment as well as decrease the streaming potential. In a similar way, it can also help augment the anisotropy as well as suppress it, depending on various external parameters. We then move on to explore the effects of non-Newtonian rheology on electroosmosis in presence of charge modulated surfaces. To this end, we study the electroosmotic flow of an Oldroyd-B type fluid, in presence of patterned surface potential, by applying a combination of singular and regular perturbation technique. We report a modified "*Slip-velocity*" for the viscoelastic fluids in the thin Double Layer limit and show that generally a non-linear rheology causes a drop in the net throughput, adding more periodicity to the flow. Our next study pertains to a very similar fluid (*Linear Maxwell model*), albeit under time periodic forcing. Interestingly, we observe a "*roll-break-up*" phenomenon, which is unique to viscoelastic fluids. We also study mixing performance of the reported flow, by exploring particle dispersion and report the effects of rheology on mixing characteristics in a narrow confinement. Our fourth topic of investigation refers to the electroosmotic flow of a superimposed fluid system, in presence of surface potential modulation. We derive approximate analytical solutions through domain perturbation and numerical solutions through "*Phase-Field formalism*", to study the flow structure and interface shape. We report that the streamlines usually get distorted in such flows, due to interface deformation, depending on the extent of anisotropy in the external parameters. In our final work, we address electroosmotic flow over potential modulated surfaces, wherein, we include the effects of ionic advection, going beyond the usual weak field approximation. We derive analytical (asymptotic) solutions for several limiting cases and also solve the relevant

equations numerically. Our general finding is that, inclusion of advection generally slows down the flow. Moreover, we observe that the effects of field strength and advections tend to play opposite roles in influencing the overall flow dynamics.

The conclusions drawn from the present thesis can bear immense consequences towards the development of small scale mixing devices, which specifically involve multiple phases, or biological fluids, which are most aptly described by non-Newtonian rheology.

Keywords: Electrokinetics, Electroosmosis, Charge Modulation, Viscoelastic, Phase Field formalism, Asymptotic Solutions, Ionic Advection, Weak Field Approximation.