Numerical Study of Electrokinetic Flows and Species Mixing in Microchannels

Chapter-1 is introductory. In this chapter we have described the basic principle of electrokinetic phenomena and their importance in microfludic system.

In Chapter-2, we have studied the combined electroosmotic-pressure driven flow and species transfer in micro/nano channels. We have investigated the mixed flow based on the non-linear Nernst-Planck (NP) model. Solutions based on the NP-model is compared with the Poisson- Boltzmann (PB) model. One of the objective of present study is to investigate the non-linear effects due to an order one Reynolds number on the electroosmotic (EO) flow with finite Debye lengths.

The effects of surface heterogeneity in wall potential on EO-pressure driven flow is investigated in Chapter-3. Both pressure-assisted and pressure-opposed electroosmotic flow (EOF) is considered in the present analysis. The present numerical model is based on the coupling of Nernst-Planck equations, Poisson equation and Navier-Stokes equations. The inertial effects on EOF near a potential patch is not negligible at lower range of the imposed pressure gradient. The dependence of the vortical flow on imposed pressure gradient and patch potential are investigated.

In Chapter-4, we have studied the combined electroosmosis-pressure driven flow near a wall mounted insulated block with heterogeneous surface potential in a microchannel. The characteristics of the electrokinetic flow are obtained by numerically solving the Laplace equation, Poisson equation, Nernst-Planck equations and Navier-Stokes equations in a coupled manner. A numerical method based on the pressure correction iterative algorithm (SIMPLE) is adopted for computation. The loss of momentum near the obstacle is compensated by the electrostatic force near the electric double layer (EDL), which prevents flow separation upstream or downstream of the obstacle.

In Chapter-5, a numerical study is made on the induced charge electroosmotic flow (ICEO) in the vicinity of a polarizable metallic obstacle mounted on one of the non-conducting walls of a microchannel. The EOF near the polarizable block is analyzed through the NP-model. For finite values of Debye layer thickness, a non-zero charge density outside the EDL occurs, which makes the ion transport equation and equation for fluid flow coupled in the bulk region of the channel. We have analyzed the effect of bulk ionic concentration on ICEO.

Keywords: Nernst-Planck equations, Species mixing, Potential patch, Surface roughness, Reynolds number, Polarizable obstacle.