Abstract

The aim of this thesis is to investigate the effects of different factors on solute transport across the porous wall of micro/nano/milli conduits. Overlapping electric double layer is formed in a microchannel if the wall potential is sufficiently high. Power law model is the prevalent rheology for the biological fluids. Thus, the transport of neutral solute across the porous wall in presence of combined electric field and pressure driven flow for a power law fluid in such a channel was studied. The electric potential distribution was obtained by coupling the Poisson's equation without considering the Debye-Huckel approximation. Transport phenomena involving mass transport of a neutral macrosolute was formulated by species advective equation and was solved semi analytically.

Effects of asymmetric electrolyte on mass transport of a neutral macrosolute in the microtube with porous wall were also investigated. The combined velocity profile including both pressure driven and electroosmotic flow was modeled for different kind of electrolytes. The developed model was validated with the experimental data, using a cartridge having hollow microtubes with porous wall. The above study was undertaken for Newtonian fluid.

The rheology of human blood resembles closely the Casson fluid. Mass transport characteristics of a neutral solute in such a fluid through a microtube with porous wall under the influence of both pressure and electric fields were studied. The velocity and concentration fields were derived from first principles analytically. A theoretical method was developed to identify the diseased state by detecting the stagnation point in the microfluidic platform without any chemical reagents. This study would be useful to diagnose the diseases, like polycythemia, hyperfibrinogenemia etc.

For a nanochannel, the size of ion influences the potential distribution as well as the solute transport. Thus, the effect of finite ion size on the transport of a neutral solute across the porous wall of a nanotube is studied. The Poisson-Boltzmann equation was modified including the ion size and it was solved without Debye-Huckel approximation. Power law fluid was selected as the prevailing rheology mimicking the real life physiological fluids. Steady state solute balance equation was solved by the similarity technique in order to track the solute transport across the tube.

Transport of salt through the wall of porous microtube is relevant in various physiological microcirculation systems. Transport phenomena based modeling of such system was undertaken considering a combined driving force consisting of pressure gradient and external electric field in case of a microtube. The solute transport through the pores of the wall was considered to be composed of diffusive, convective and electric potential gradient governed by the Nernst-Planck equation. The same model was used to track the transport of sodium chloride across the pores of a nanofiltration membrane having a milli channel. The contributions of convection, diffusion and electromigration towards the solute flux within the membrane pore were estimated. The calculated permeate flux and the solute concentration in the permeate were compared with the available experimental data.

The effects of porosity of the wall become dominant on the velocity field as the size of the flow channel is reduced to micro level or even less (nano level). An analytical solution of the velocity field in a microchannel with porous wall was obtained for a Newtonian fluid, in case of a combined electroosmotic and pressure driven flow, by perturbation technique. The velocity profile was computed and compared to well-known solutions for three asymptotic cases, namely, pure electroosmotic flow, pressure driven flow in an impervious conduit and pressure driven flow with permeable walls.

The works presented in this thesis provide a theoretical understanding of the solute transport across the porous wall of micro/nano conduits and presents a guideline to fine-tune the operation of porous conduit based microfluidic devices for various applications.

Keywords: Microchannels; porous wall; over lapped electric double layer; asymmetric electrolyte; Casson fluid; finite ion size; salt transport.