SUMMARY OF Ph.D. DISSERTATION

School	Student Identification Number	SURNAME, First name
Integrated Design Engineering		KAZOE, Yutaka

Title

Electroosmotic Flow Structure in Microchannel with Nonuniform Wall Zeta-Potential Measured by Fluorescence Imaging Technique

Abstract

Microscale liquid flows under electric field, i.e., electroosmotic flows, have been widely used in the microscale flow systems such as capillary electrophoresis and micro total analysis systems. However, the absence of two-dimensional measurement techniques for key parameters of electroosmotic flow, i.e., the time dependent flow velocity and the wall zeta-potential, has prevented experimental approaches to the flow with nonuniform wall zeta-potential by the material heterogeneity in a channel and the ion and thermal transport with mixing and chemical reaction. The present study developed a velocity measurement technique and a nanoscale laser induced fluorescence imaging for the zeta-potential measurement, and investigated electroosmotic flow with nonuniform wall zeta-potential. The momentum transport in the flow field and the effect of the ion motion on the zeta-potential distribution were evaluated.

Chapter 1 describes introduction to electroosmotic flow, reviews the related previous work, and presents the objectives of the present study.

Chapter 2 summarizes the governing equations for microscale flows, fabrication techniques of microchannels, and fundamentals of measurement techniques based on fluorescence imaging.

Chapter 3 presents a time-resolved velocity measurement technique using particle tracking velocimetry for transient electroosmotic flow with the time scale of 10^{-3} s. An iterative measurement was conducted to increase the spatial resolution, based on the reproducibility of low Reynolds number flow. The combined measurement of near-wall and bulk velocities was achieved by a system using the evanescent wave and the volume illumination.

Chaper 4 presents the nanoscale laser induced fluorescence imaging using fluorescent dye and the evanescent wave generated in the vicinity of the wall with the order of 100 nm. Since the fluorescence ions are distributed depending on the wall zeta-potential, the zeta-potential can be obtained from the fluorescent intensity excited by the evanescent wave. A two-prisms based evanescent wave illumination system was developed to achieve the large area measurement.

Chapter 5 presents the investigation of transient electroosmotic flows in microchannels with uniform material, heterogeneous material and the surface modification on the channel wall. Electroosmotic flows with the channel scale of 10^{-4} m reached to the steady state at the time about 10^{-3} s after the electric field was applied. Electroosmotic flows have different velocity profiles by the pattern and magnitude of wall zeta-potential, but the volumetric flow rate and the averaged zeta-potential shows a proportional relationship.

Chapter 6 presents the examination of electroosmotic flow with mixing of two electrolyte solutions at different ion concentrations. The measured zeta-potential distribution at the channel wall shows a quantitative relationship with the local ion concentration governed by the convection and diffusion with the mixing. Electroosmotic flow was generated by the zeta-potential distribution at the wall, which is dependent on the ion motion.

Chapter 7 describes the conclusions, and shows potential applications of the measurement techniques developed in this work for the microscale flow systems.