147g Semi-Analytical Prediction of the Shape Change of Electrolyte Droplet on the Electrode Including the Ion Number Constraints

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In the electrowetting of the micro-sized or smaller, closed system, such as nano-sized droplet in nano-tube, the assumption of infinite domain of Poisson-Boltzmann equation may not be satisfied. The Debye length is not negligible compared to the system length when the concentration is not very high. Then, we cannot neglect the finiteness of the number of ions and cannot define the bulk position for the system. In the present work, we use a different governing equation including the ion number constraints by combining the Poisson equation for electrostatics and Nernst-Planck equation for ionic flux in the electrolyte (so called, Poisson and Nernst-Planck equation with constraints of the number of ions). This is more general form of the Poisson-Boltzmann equation. The solutions obtained by Poisson and Nernst-Planck equation with constraints for the number of each species of ions(PNPc) are compared with the Poisson- Boltzmann equation(PB). The electrostatic potential, the surface forces by the electric stress and the osmotic pressure on the drop surface are predicted by PB and PNPc for different value of key parameters: the ratio of the system length and the Debye-length ($\kappa l c$) and the potential difference ($\Delta\varphi$) between top and bottom electrode. Due to the non-linearity of those equations, numerical approach is taken. It is based on a finite-difference solution on each governing equation on the spherical coordinate. Finally, the shape change of droplet is predicted semi-analytically. The surface force is obtained by solving PNPc numerically and the equilibrium shape(in 2-dimension) of droplet is predicted by using analytic relation between with the curvature and the normal stress. It is shown that the macroscopic shape change in electrowetting can be made by the electric contribution, not by the molecular contribution.

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