The Effects of the Electrical Double Layer on Giant Ionic Currents Through Single Walled Carbon Nanotubes

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Abstract

Electrofluidic transport through a single walled carbon nanotube (SWCNT) is enhanced by electroosmosis. Electroosmosis is made possible in these devices by the combination of a large slip length within SWCNTs and the interfacial potential at the solution/nanotube interface. A computational model of a SWCNT device was developed using COMSOL Multiphysics to investigate the complete electrical double layer structure with the consideration of electroosmostic force in addition to electric mobility force. The thickness of the compact layer was iteratively adjusted and found to increase with solution concentration. The relationship between conductance and concentration found in the model fit the correlation predicted from experimental results in the literature. By including an explicitly defined Stern layer with a spatially varying dielectric permittivity, the model accounts for the complete Gouy-Chapman-Stern electrical double layer and surface potential at the channel wall. The validity of the model was verified by comparing the output of the model with experimental data found in literature. Key metrics in validating the model were internal consistency (agreement between current probes at various lengths along the nanotube) and conductance/concentration relationships. The observed current response was due to the combination of electrophoresis and electroosmosis facilitated by an effectively perfect slip plane at the solution interface of the compact layer. The thickness of the compact layer is non-negligible and contributes to the observed relationship between conductance and concentration. The improved model presented here replicates the experimentally observed behavior of single walled carbon nanotubes while remaining in harmony with current electrochemical theory.