Center for Fluid Mechanics, Division of Applied Mathematics
Fluids and Thermal Systems Group, School of Engineering
Joint Seminar Series

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Nanofluidic Diodes and Electrokinetic Biosensors

We examine the mechanisms behind ion current rectification of asymmetric ion-selective nanopores and nanoslits----and nanoporous membranes in general. The low voltage mechanism is due to intra-pore longitudinal asymmetry in surface charge or pore cross-section area. We show that a Donan potential gradient due to this asymmetry is responsible for the low-voltage rectification and this gradient disappears at high and low bulk ionic strengths. Asymptotic estimates for the rectification factor of a conic pore are derived at both limits and yield an optimal ionic strength for maximum rectification. At large voltages, when micro-vortices appear at one pore entrance due to extended polarization, we show asymmetry in the hydrodynamic resistance at the two entrances is responsible for the rectification phenomenon. Depending on the geometry at the entrance and the voltage, these vortices could be stationary or could fluctuate dynamically with intermittent coalescence and creation events. They create broadband fluctuations in the overlimiting currents of the nanopore/membrane. We show that nucleic acid hybridization at the entrance can introduce sufficient change in the hydrodynamic slip length to produce large rectified ionic current changes, allowing for sensitive detection of DNAs with probe-functionalized ion-selective membranes. This hydrodynamic (electrokinetic) biosensor is much more selective than electrochemical sensors because spurious electron-transfer reactions are eliminated. We also show that, with proper design, convection by the microvortices and dielectrophoretic molecular trapping by the high field at the extended polarization region can significantly reduce the assay time.

TUESDAY – SEPTEMBER 20 , 2011

4:00 PM

Barus & Holley, Room 190