Nanofluidic Gates and Ionic Transistors

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Goals

• Sub-molecular control and sensing
• Nanoscale, non-functionalized detection
• Nanopores as nanofluidic transistors
Experimental Setup

Ag/AgCl Electrodes

Flow Cell

Pore Chip
Numerical Model

• Axisymmetric conical nanopore
COMSOL Modeling

• Electrostatics:
  \[ \nabla^2 V = -\frac{\rho_c}{\varepsilon_0 \varepsilon_r} \]

• Transport of Dilute Species:
  \[ \nabla \cdot \left( -D_j \nabla c_j - z_j \mu_{m,j} F c_j \nabla V \right) + u \cdot \nabla c_j = R_j \]

• Creeping Flow:
  \[ \rho_v (u \cdot \nabla) u = \nabla \left[ -PI + \gamma \left( \nabla u + (\nabla u)^T \right) - \frac{2}{3} \gamma (\nabla \cdot u) I \right] + \vec{F}_V \]
  \[ \nabla \cdot (\rho_v u) = 0 \]
Experimental Results

- On/off states
- Conductance proportional to bias

Applied Bias (mV): -600, -400, -200, 0, 200, 400, 600

Transconductance (nS): -40, -20, 0, 20, 40, 60, 80

Current (nA): -15, -10, -5, 0, 5, 10, 15

Time (s): 0, 50, 100, 150, 200, 250

Graphs showing experimental average, wide angle model, and narrow angle model for applied bias and transconductance.
Gating Mechanism

• Gating due to locked ion selective regions
Ionic Current Mechanism

• Electrophoretic dominant current
Summary

• The ionic current could be gated by switching the polarity of the bias
• On-state conductance is proportional to bias
• Electrophoretic conduction mechanism
Conclusions and Future Work

• Actively controlled nanoscale pumps with precise conductance
• Ionic transistors (On/Off current gating)
• Demonstrated active control of nanopore transport properties
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References


