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Nanofluidic Gates and Ionic Transistors

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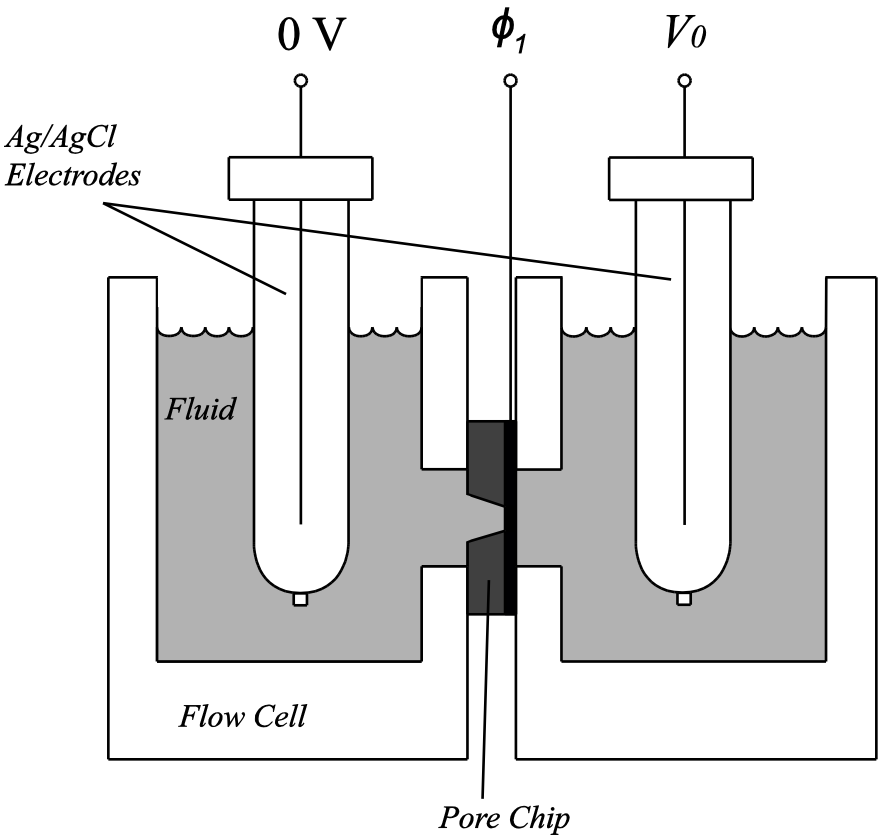
Goals

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

Experimental Setup



Numerical Model

- Axisymmetric conical nanopore

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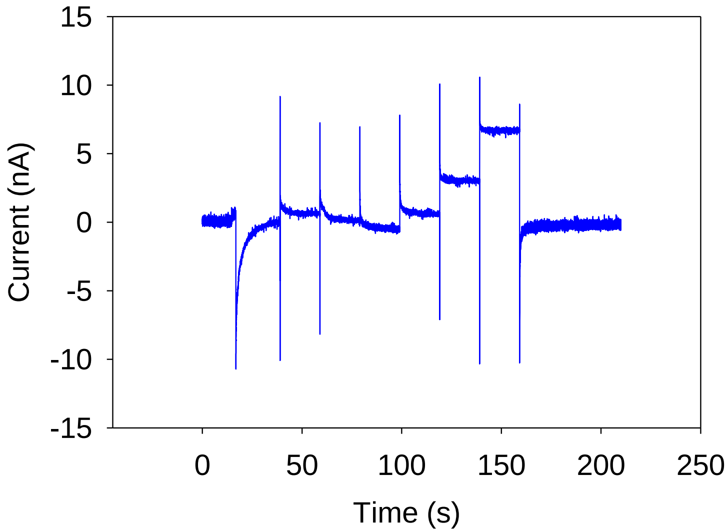
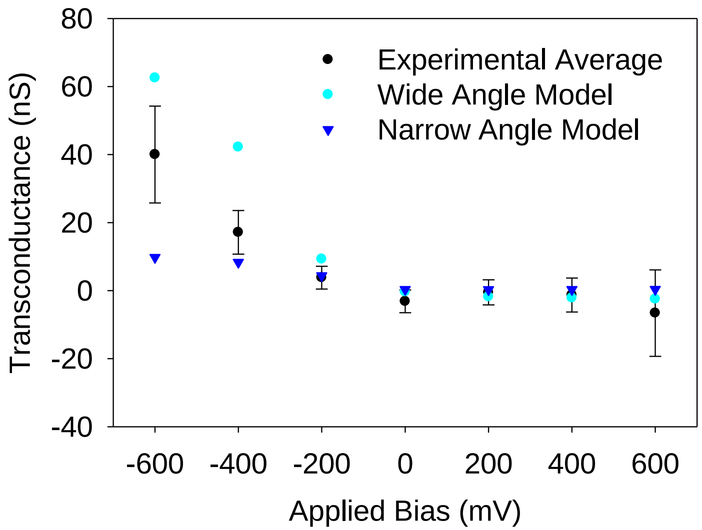
COMSOL Modeling

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

Experimental Results

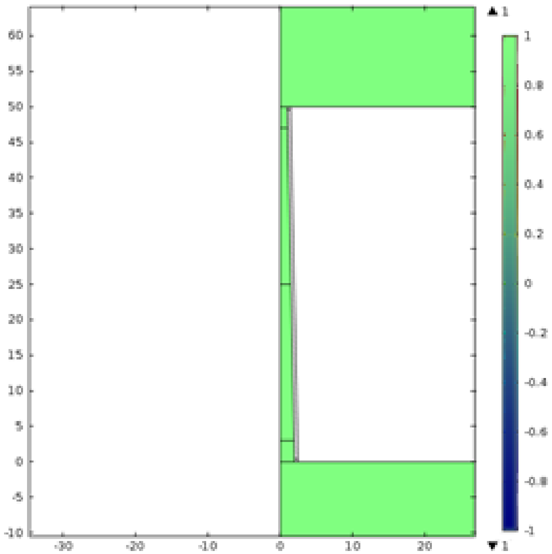
- On/off states
- Conductance proportional to bias

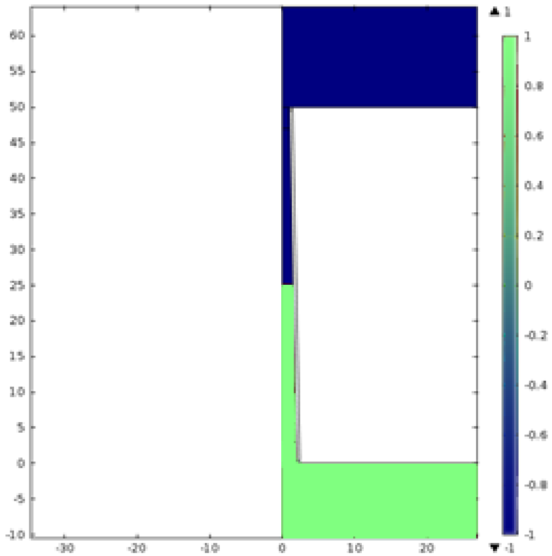


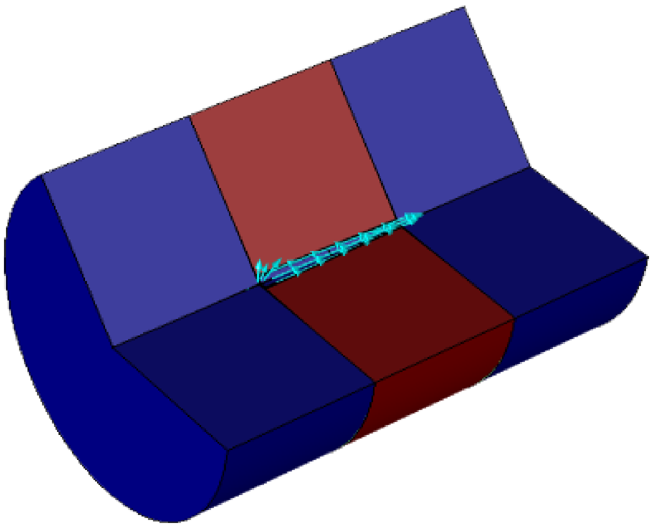


Gating Mechanism

- Gating due to locked ion selective regions

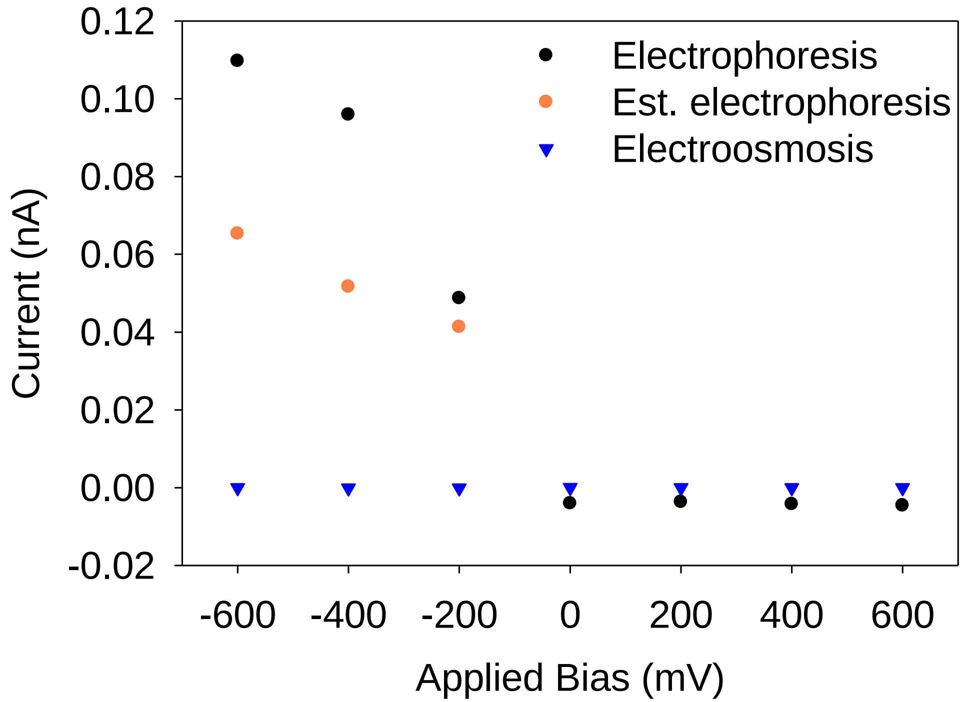






Ionic Current Mechanism

- 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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