A Lattice Boltzmann Study of Surface-Directed Liquid Flows in a Microchannel

Taehun Lee and Ching-Long Lin

Mechanical & Industrial Engineering, IIHR – Hydroscience & Engineering

1. Flows on a Micro-Scale

- Characteristics of micro-flows: large surface-to-volume ratio

  (*surface effects ~ r^2 vs. volume effects ~ r^3*)
- Dominant factors
  - Surface tension → Capillary effect
  - Viscosity
  - Electrical charges
- *Required*: New class of modeling techniques (Fig.1)
- Lattice Boltzmann Equation (LBE) method: Emerging computational method for simulation of mesoscopic phenomena with interfaces b/w two liquids and liquid/solid

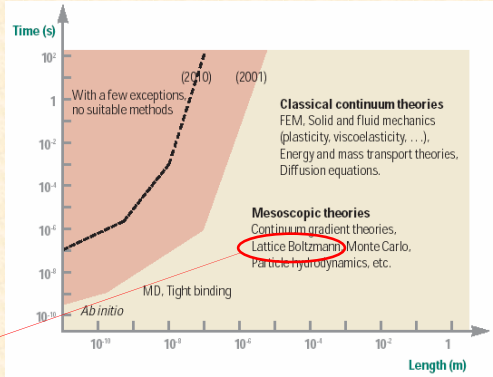

Fig. 1. Modelling strategies for nano- and biomaterials (Gao, 2001)

2. Liquid Flows in a Surface-Directed Microchannel

- Aqueous solutions flow only along hydrophilic pathways
- ***"Virtual Walls"***: Interfaces b/w two fluids (cf. solid walls)
- Applications (*Zhao et al.*)
  - Pressure-sensitive valve (Fig.3): Virtual walls can rupture at increased pressure
  - Chemical reaction enhancement (Fig.4): Solution color changes
  - Biosensor (Fig.5): Selective sensing b/w ions and ionophores

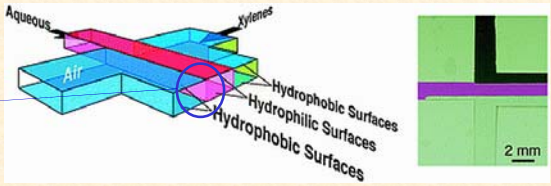

Fig. 2. Virtual walls by Zhao et al.(2001): Inner surfaces are chemically patterned to have hydrophilic surfaces while outer surfaces to have hydrophobic surfaces

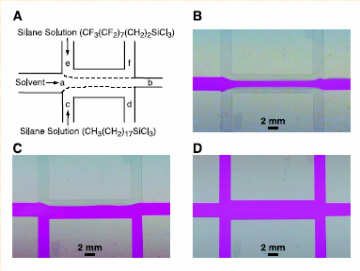

Fig. 3. Pressure-sensitive valve

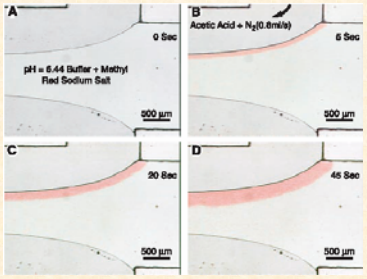

Fig. 4. Chemical reaction at virtual walls

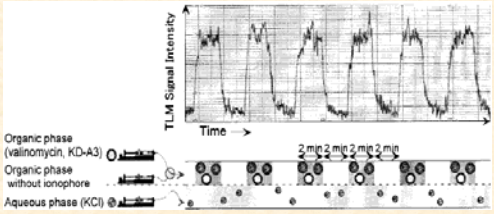

Fig. 5. Selective sensing at virtual walls

3. Research Objective: To study instability and detailed flow physics of virtual walls due to pressure and surface patterning using lattice Boltzmann method.

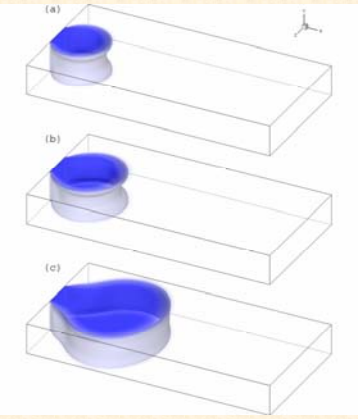

Fig. 6. No surface patterning: No Virtual Walls

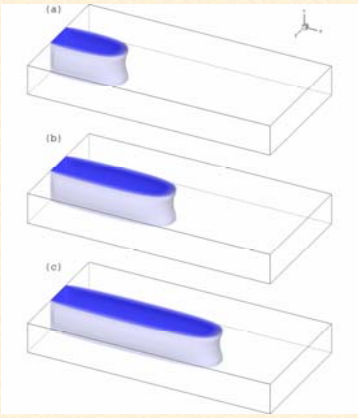

Fig. 7. At moderate pressure: Virtual Walls sustain

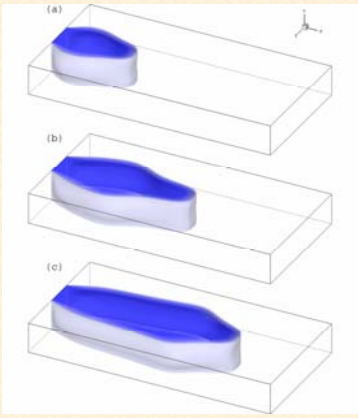

Fig. 8. At higher pressure: Virtual Walls rupture

4. Ongoing/Future Work

- Adding **macromolecules** such as DNA molecules and polymer to surface-directed liquid systems to examine effect of virtual walls on conformation dynamics of macromolecules