ME 517: Micro- and Nanoscale Processes

Lecture 35: Surface Tension Microfluidics

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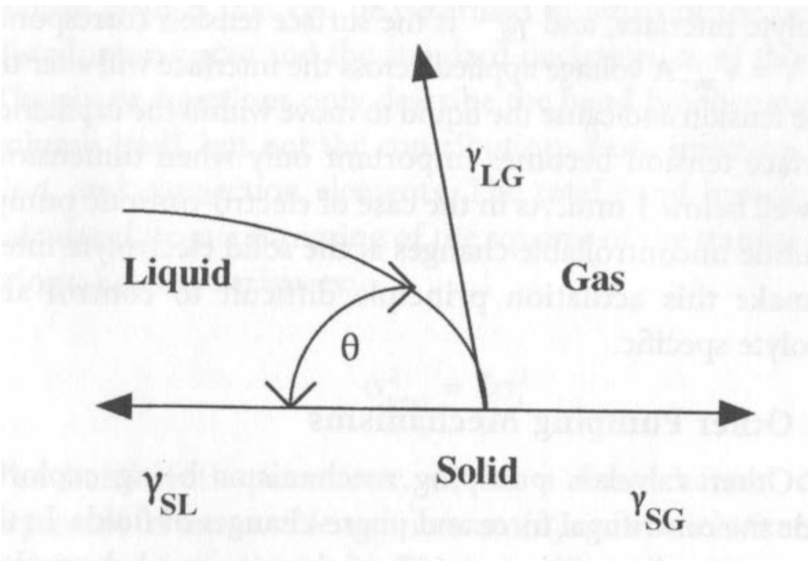
Surface Tension Microfluidics

- Introduction to surface tension
- Thermocapillarity
- Electrowetting
  - Electrowetting on dielectric (EWOD)
  - Open opto-electrowetting (O-OEW)
  - Electrowetting + particle manipulation

Surface Tension Basics

Surface tension (γ) is the increase in energy as the surface area increases.

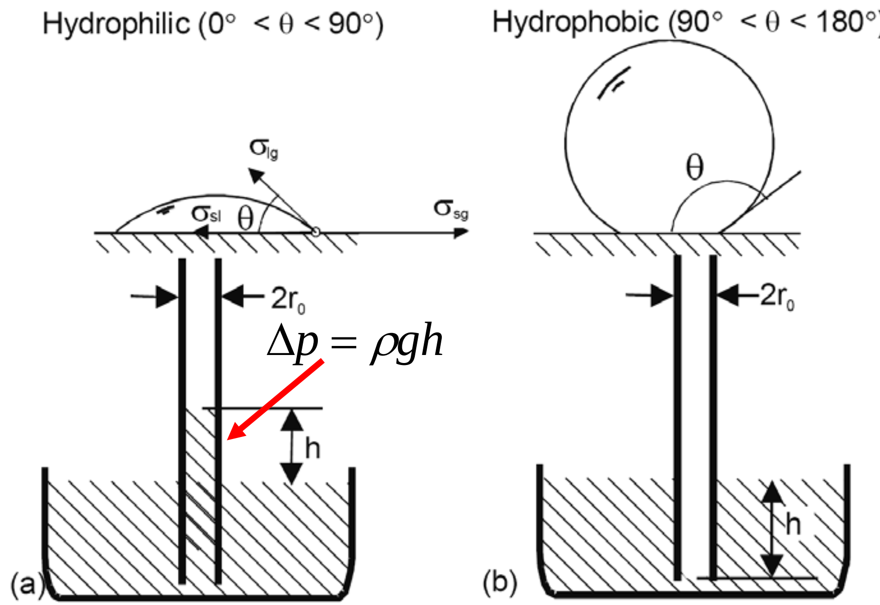


Young's Equation

$$\gamma_{SL} + \gamma_{LG}\cos\theta = \gamma_{SG}$$

$$\Delta p = \frac{2(\gamma_{SG} - \gamma_{SL})}{r} = \frac{2\gamma_L \cos\theta}{r}$$

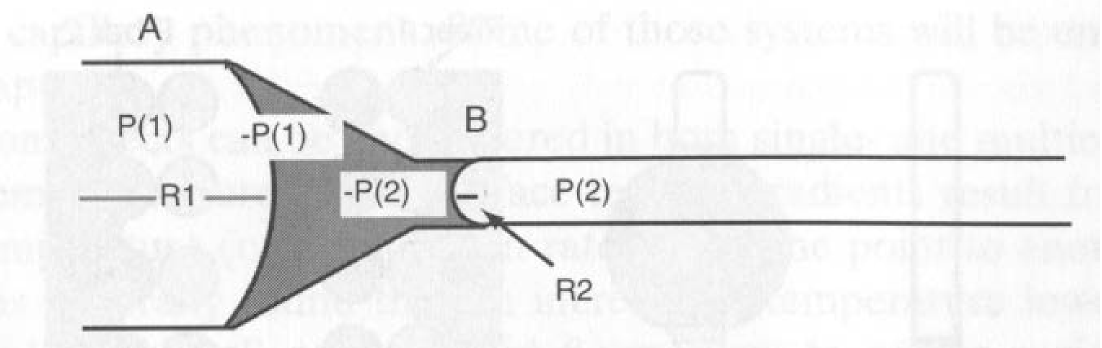
γ_{water} = 72.8 mN/m
r = 10^{-6} m
Δp ~ 100 kPa or 1 atm



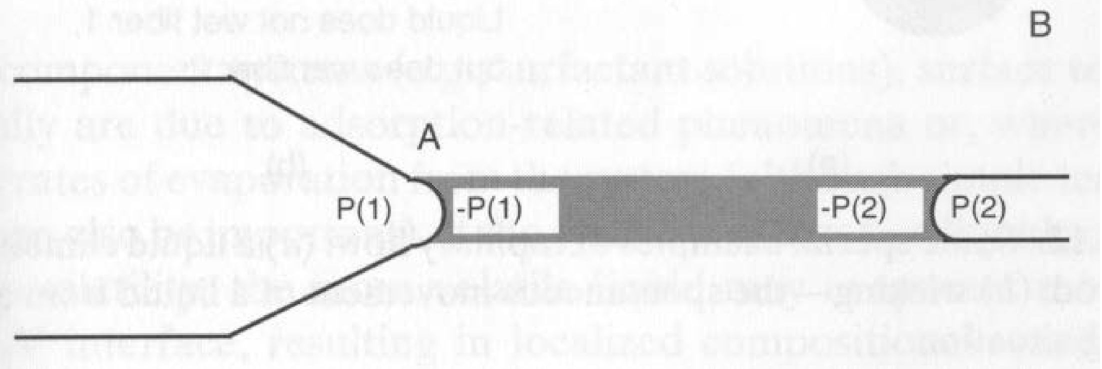
Capillary force driven pumping: (a) hydrophilic; and (b) hydrophobic.

Surface Tension Basics

Capillary tube wetting



Unstable

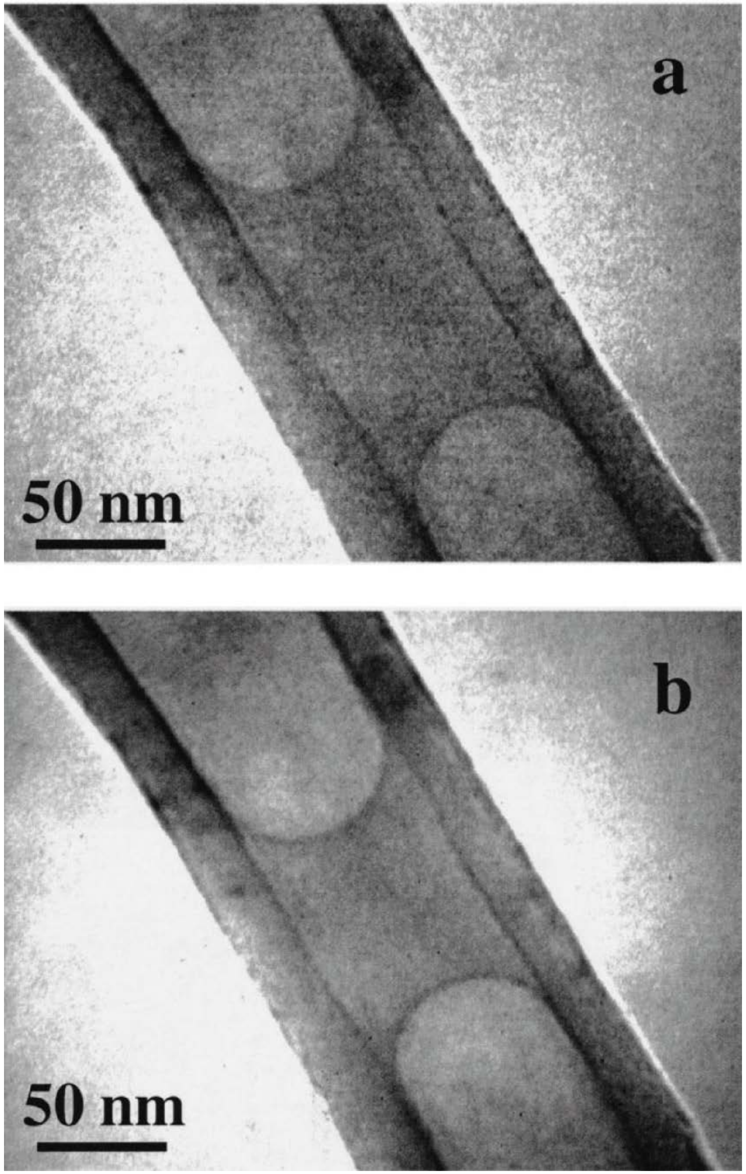


Stable = Stuck!

Microdevice here   Water strider here

Water in Carbon Nanotubes

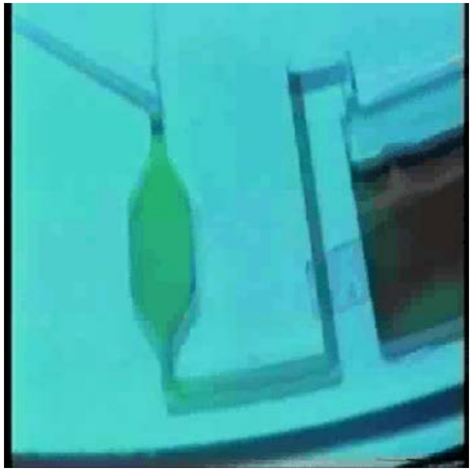
Megaridis, Phys. Fluids, Vol. 14, pp L5-L9, 2002

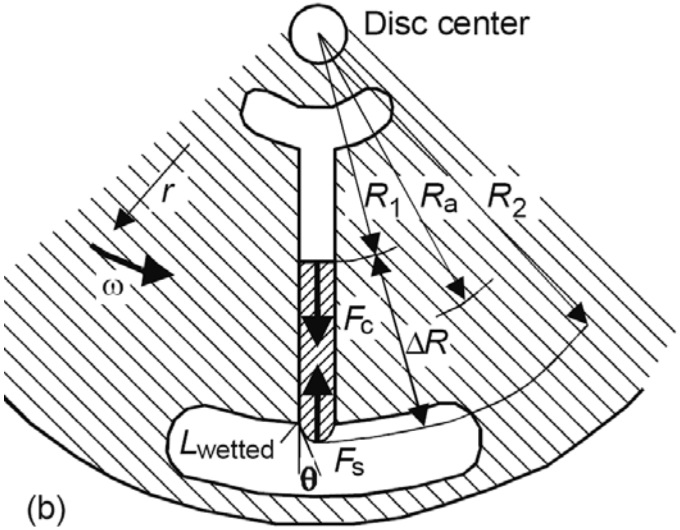


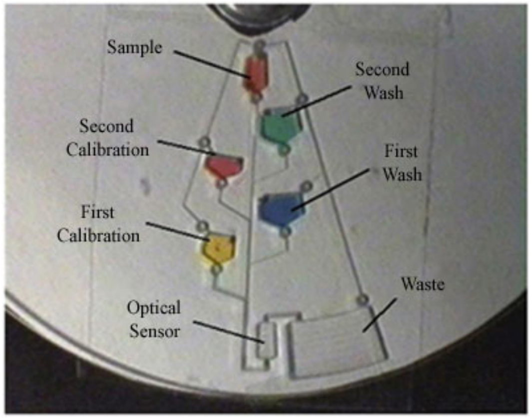
- Hydrothermally produced multi-wall carbon nanotube
- Water inside nanotube
- TEM micrographs of meniscus
- Water volume decreases from a to b upon heating
- Explanations:
  - Bubble expansion
  - Liquid evaporation
  - Thermocapillarity
- Results inconclusive

Surface Tension Valves

Lab-on-a-Disk: Marc Madou, UC-Irvine







Centrifugal Force: $$\frac{dF_c}{dr} = \rho\omega^2 r$$

Surface Tension: $$F_s = \frac{\sigma \cos\theta \, L_{wetted}}{A}$$

Burst Frequency: $$f_b \geq \sqrt{\frac{\sigma \cos\theta}{\pi^2 \rho R_a \Delta R D_h}}$$

Movie here