Lecture 10: Surface Micromachining II

- Announcements:
- HW #2: Due today
- HW#3: Online soon, due Thursday next week
- No lecture Thursday, 9/29
- Makeup lecture in new screencast-capable room:
  - 2 LeConte, from 3-5 p.m., on Friday, 9/30
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- Today:
- Reading: Senturia Chpt. 3, Jaeger Chpt. 11, Handout: "Surface Micromachining for Microelectromechanical Systems"
  - Lecture Topics:
  - Polysilicon surface micromachining
  - Stiction
  - Residual stress
  - Topography issues
  - Nickel metal surface micromachining
  - 3D "pop-up" MEMS
  - Foundry MEMS: the "MUMPS" process
  - The Sandia SUMMIT process
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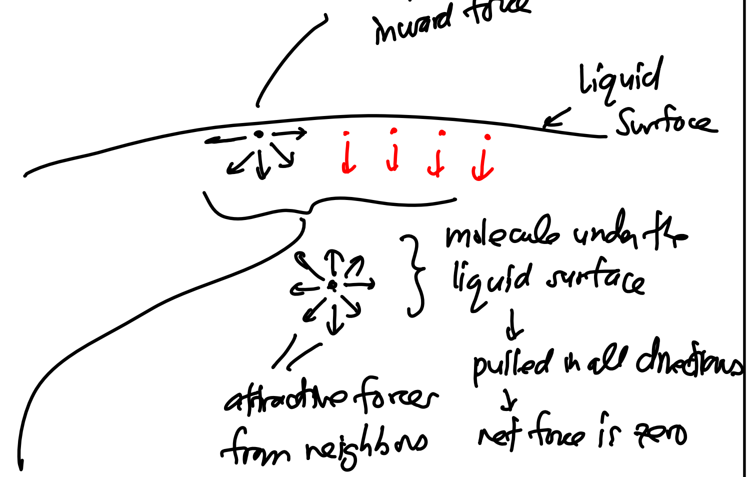
- Last Time:
- Going through Module 5 on Surface Micromachining
- Left off on stiction

Microstructure Stiction

Surface Tension

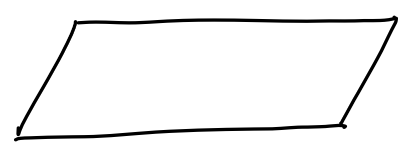
molecule @ liquid surface ⇒ experiences a net inward force



Equilibrium (nothing is moving) → forces balanced out by liquid's resistance to compression!

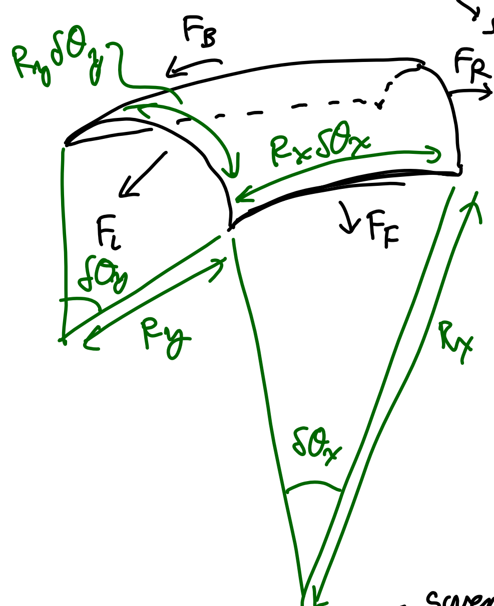
⇒ Result: liquid squeezes to achieve the smallest surface area (smallest energy state)

Surface Curvature & Pressure



No pressure difference → surface remains flat

⇒ upon introduction of a differential pressure → surface curves to generate a net normal force to maintain equilibrium against the pressure



Young-Laplace Equation ← governs the shape of the liquid

$$\Delta p = \gamma\left(\frac{1}{R_x}+\frac{1}{R_y}\right)$$

where $\Delta p \triangleq$ pressure difference

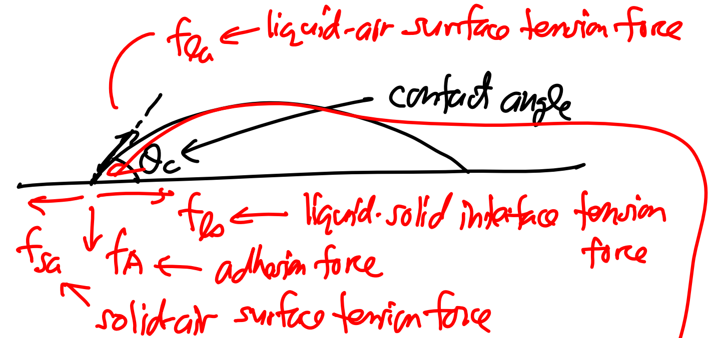
$\gamma \triangleq$ surface tension (force/length)

R_x & $R_y \triangleq$ radii of curvature

Contact Angle → dictated by a balance of surface tensions

→ really a property dependent on the interface between different materials

Example: Hydrophillic Droplet



Equilibrium: ① horizontal forces cancel ② vertical forces cancel } @ the contact pt.

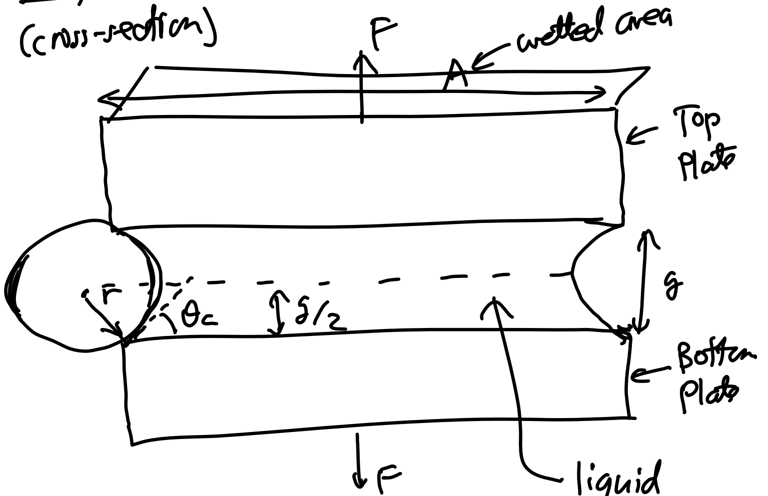
$$f_A = f_{la}\sin\theta_c$$

$$f_{sa} = f_{ls} + f_{la}\cos\theta_c \rightarrow \boxed{\gamma_{sa} = \gamma_{ls} + \gamma_{la}\cos\theta_c}$$

[for γ]

Relationship between surface tensions can be captured by contact angle.

Example: Two Plates
(cross-section)



Laplace Equation:

$$\Delta p_{la} = \frac{\gamma_{la}}{r}$$

γ_{la} ← surface tension @ the liquid-air interface

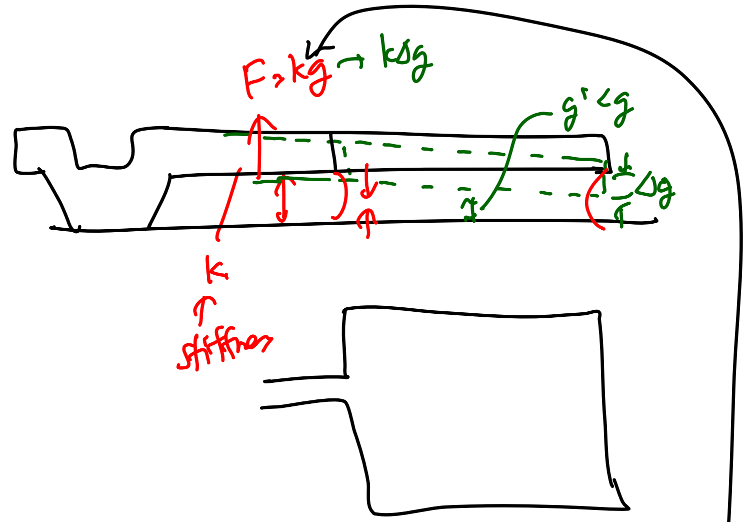
r ← radius of curvature of the liquid [(-) if convex]

Δp_{la} ↑ Pressure Difference @ the Liquid-Air Interface

$$\left[r = \frac{-(g/2)}{\cos\theta_c} \right] \Rightarrow \boxed{F = -\Delta p_{la} A = \frac{2A\gamma_{la}\cos\theta_c}{g}}$$

↑ Force needed to keep the plates apart.

⇒ (+) force means (-) laplace pressure



Remarks:

① To prevent stiction:

⇒ reduce A (wetted area)

⇒ reduce γ_{la} → choose the right liquids (& solids)

⇒ make g large

⇒ increase k → make things thicker

⇒ $\theta_c > 90°$

Liquid	Solid	Contact angle
water ethanol diethyl ether carbon tetrachloride glycerol acetic acid	soda-lime glass lead glass fused quartz	0°
water	paraffin wax	107°
	silver	90°
methyl iodide	soda-lime glass	29°
	lead glass	30°
	fused quartz	33°
mercury	soda-lime glass	140°

Some liquid-solid contact angles[5]