Lecture 8: Surface Micromachining II

- Announcements:
- HW#2 due Tuesday, 2/25, at 8 a.m.
- Surface Micromachining Module 5 online
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- Today:
- Reading: Senturia Chpt. 3, Jaeger Chpt. 11, Handouts: "Surface Micromachining for Microelectromechanical Systems", "Etch Rates for Micromachining—Part II"
- 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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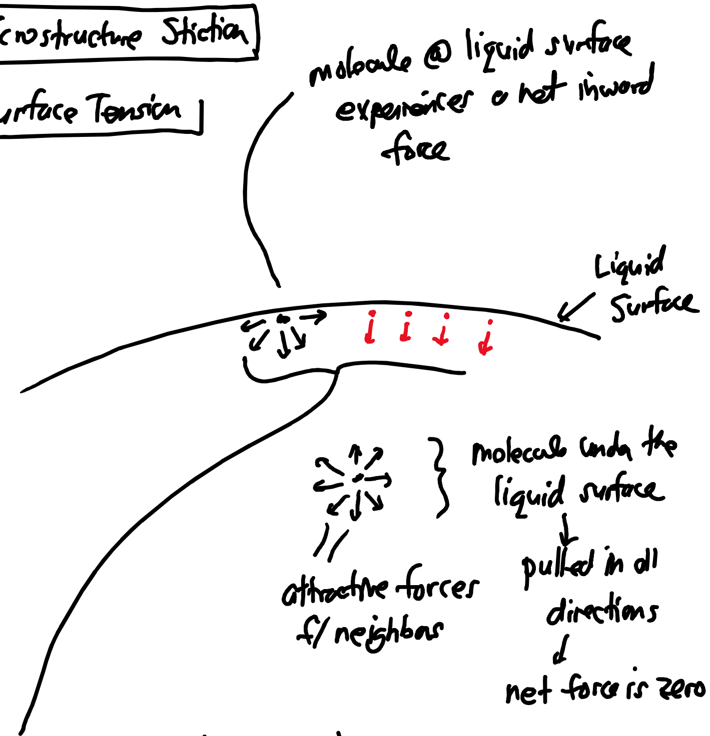
- Last Time:
- Started into Module 5
- Now continue …

1

Microstructure Stiction

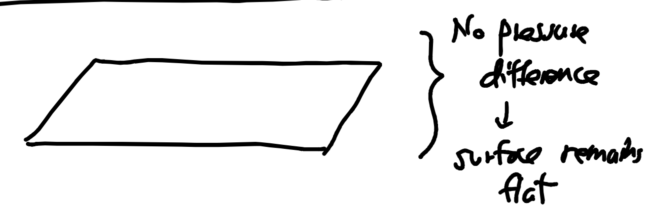
Surface Tension



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

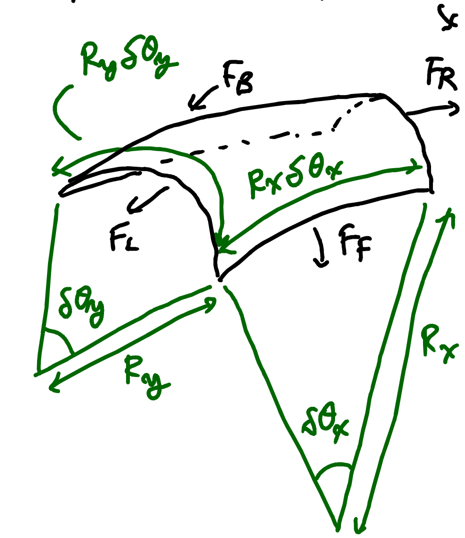
⇒ Result: liquid squeezes to achieve the smallest surface area (smallest energy state)

Surface Curvature & Pressure



2

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



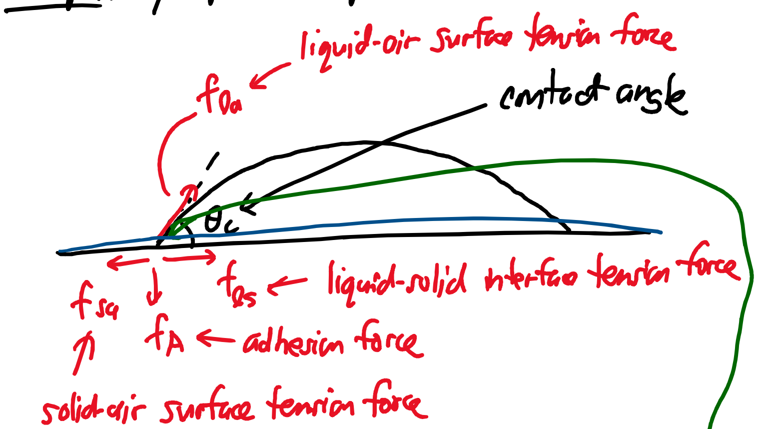
Young-Laplace Equation ← governs the shape of the liquid

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

where $\Delta p \triangleq$ pressure difference
$\gamma \triangleq$ surface tension (force/length)
R_x & $R_y \triangleq$ radii of curvature

Contact Angle → governed by a balance of surface tensions
↳ really a property dependent on the interface between different materials

Example: Hydrophillic Droplet



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

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

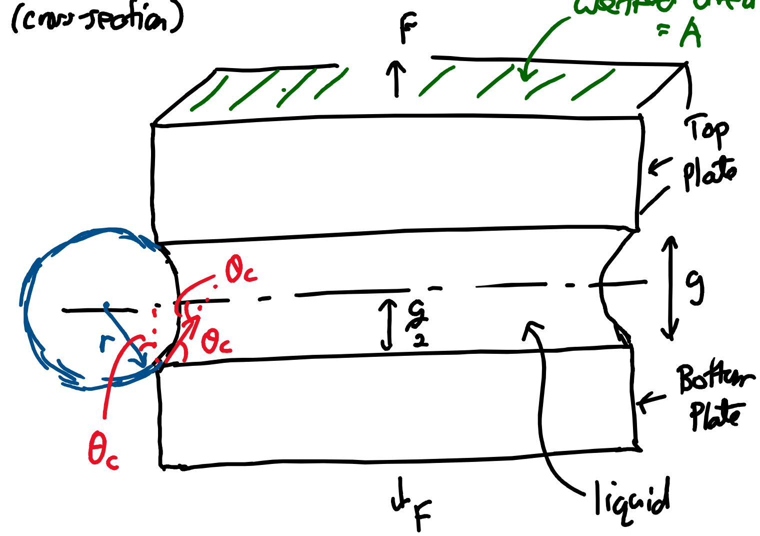
$f_{sa} = f_{ls} + f_{la}\cos\theta_c \rightarrow$ $\boxed{\gamma_{sa} = \gamma_{ls} + \gamma_{la}\cos\theta_c}$

↑ $f \propto \gamma$

Relationship between surface tensions can be captured by contact angle.

Example: Two Plates

(cross-section)



Laplace Equation:

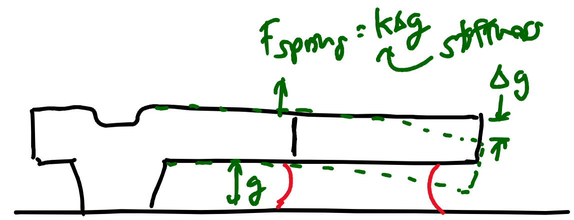
$$\Delta p_{la} = \frac{\gamma_{la}}{r}$$

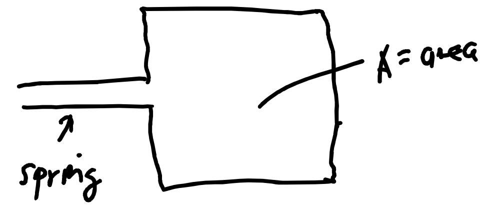
- γ_{la} ← surface tension @ the liquid-air interface
- r ← radius of curvature of the liquid [(−) if convex]
- Δp_{la} ← Pressure Difference @ the Liquid-Air Interface

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

↑ 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
- ⇒ make g = large
- ⇒ increase k → make things thicker
- ⇒ $\theta_c > 90°$ (choose the right solid/liquid combination)

Liquid	Solid	Contact angle
water	soda-lime glass lead glass fused quartz	0°
ethanol		
diethyl ether		
carbon tetrachloride		
glycerol		
acetic acid		
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]

7