Lecture 7: Surface Micromachining I

- Announcements:
- HW#2 due Tuesday, 2/25/20
- 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 …

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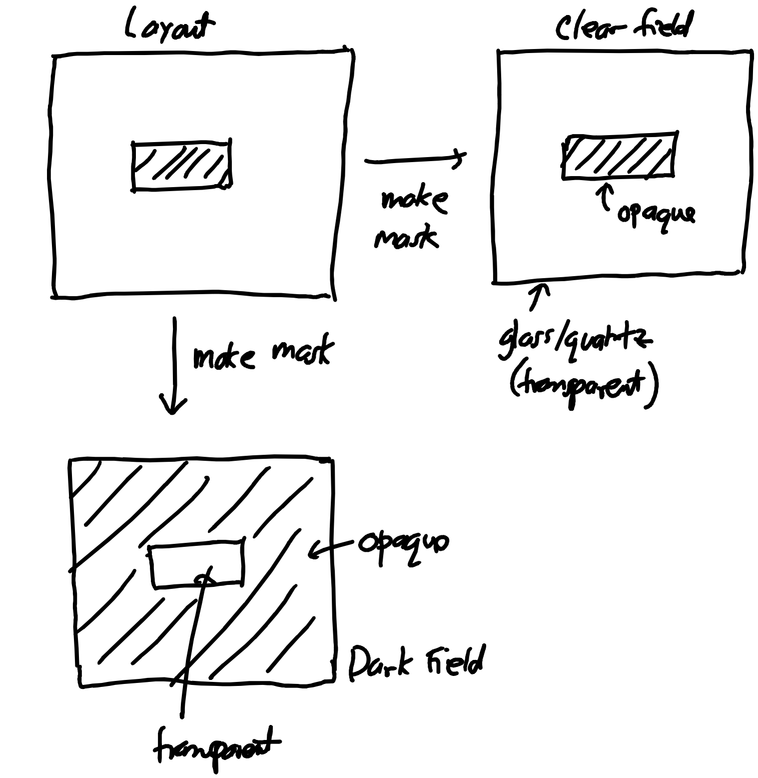
Clear-Field & Dark Field Masks



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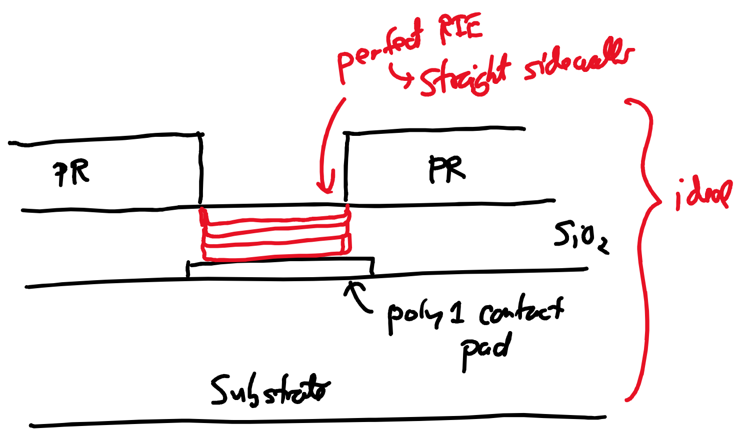
- Straight or Sloped Sidewalls:
- Often want sloped sidewalls in order to reduce the sharpness of corners
  - Easier to deposit over
  - Sharp corners concentrate stresses
  - High stress can weaken structures creating a reliabilty concern
  - High stress can dissipate energy, lowering Q
- When you want straight sidewalls (e.g., for lateral electrostatic drive), use a hard mask
  - PR can't last for thick structures
  - A hard mask suppresses angle transfer

Etching Sloped Sidewalls



⇒ above assumes perfect anistropy in RIE

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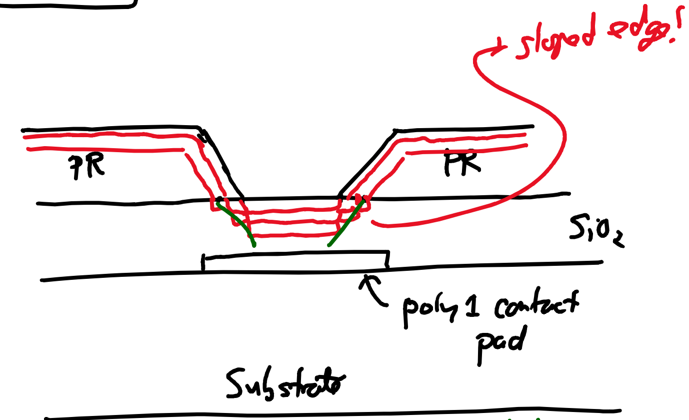
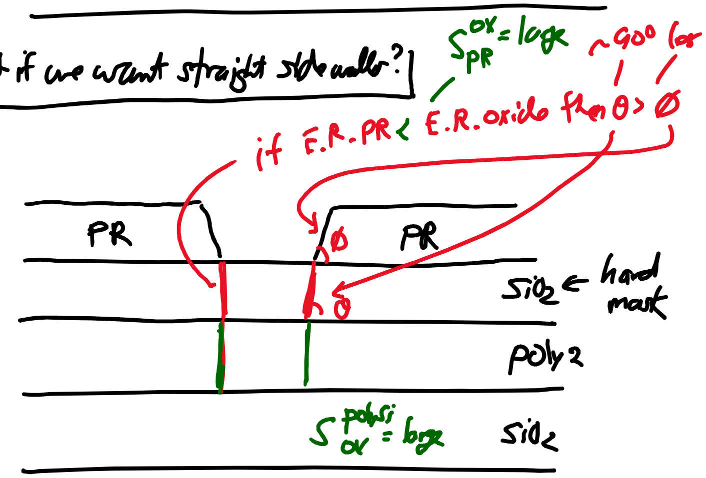
Keeping an anisotropic RIE, how can we get sloped Sidewalls



What if we want straight sidewalls?



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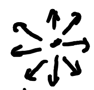
Microstructure Stiction

Surface Tension

molecule @ liquid surface experiences a net inward force

Liquid Surface



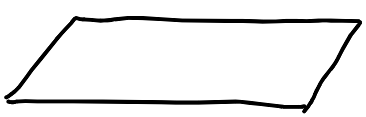
molecules under the liquid surface → pulled in all directions → net force is zero

attractive forces f/ neighbors

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



No pressure difference → surface remains flat

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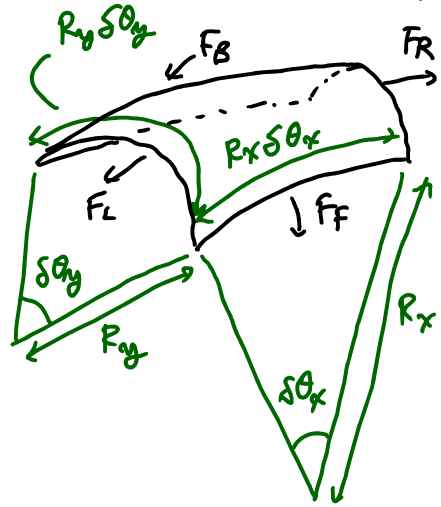
⇒ upon introduction of a differential pressure & surface curves to generate a net normal force to maintain equilibrium against the pressure



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

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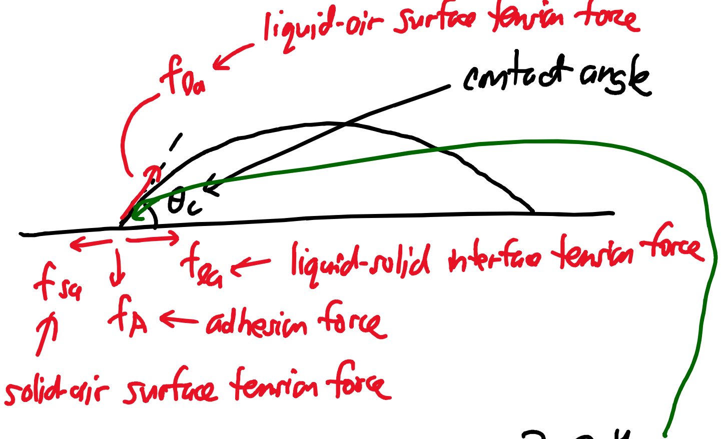
Example. Hydrophillic Droplet



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.

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