Lecture 8: Surface Micromachining I

- Announcements:
- HW#2 due Thursday, 2/15 at 10 a.m.
- Handout online: paper titled "Surface Micromachining for Microelectromechanical Systems"
- Handout online: paper titled "Etch Rates for Micromachining—Part II"
- Kieran out of town; Alper Ozgurluk taking TA duties for this week and next
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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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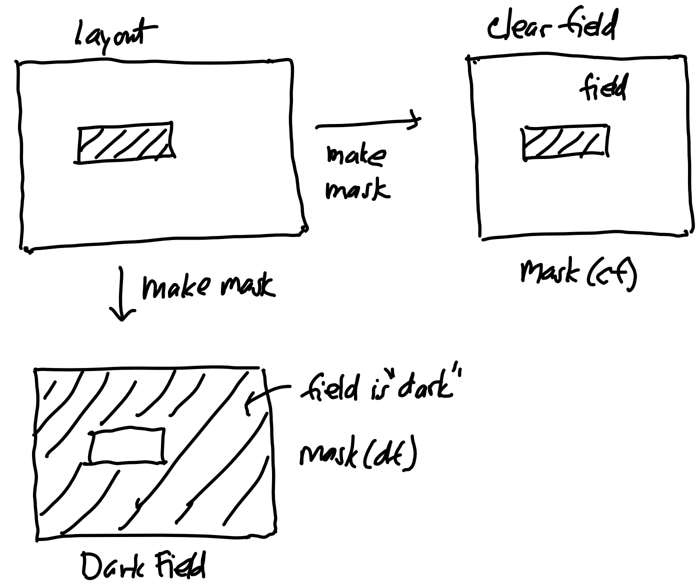
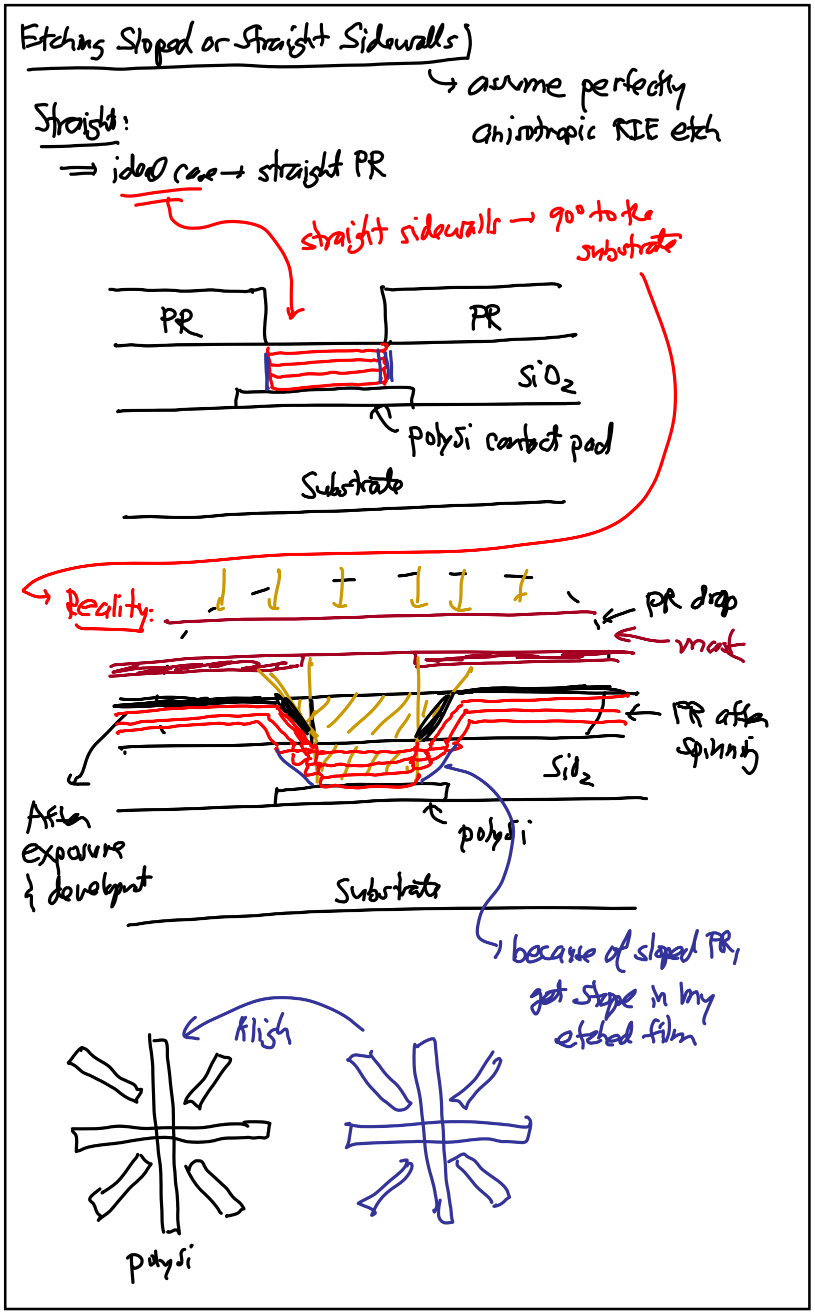
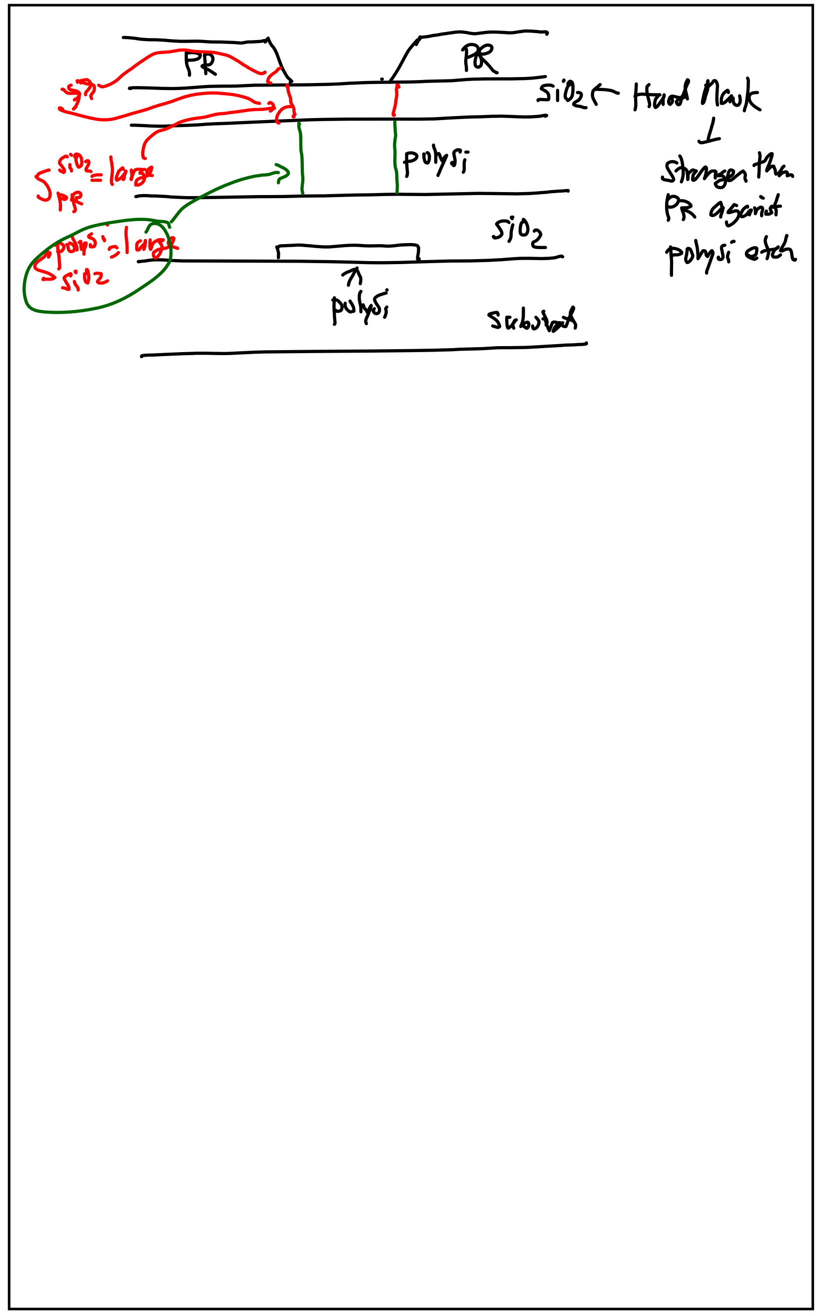
- Last Time:
- Started Module 5 on Surface Micromachining

Clear & Dark Field Masks



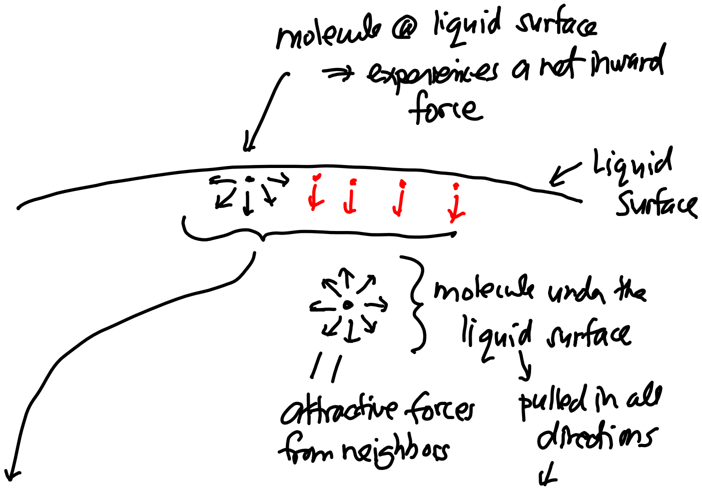
- Straight or Sloped Sidewalls:
- Often want sloped sidewalls in order to reduce the sharpness of corners
  - Easier to deposit over
  - Sharp corners concentrate stresses
  - High stress can weaken structures creating a reliabilty concern
  - High stress can dissipate energy, lowering Q
- When you want 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 or Straight Sidewalls)
assume perfectly anisotropic RIE etch
Straight:
⇒ ideal case → straight PR
straight sidewalls → 90° to the substrate
PR
PR
SiO2
polySi contact pad
Substrate
Reality:
PR drop
mask
PR after spinning
SiO2
polySi
Substrate
After exposure & development
because of sloped PR, get slope in my etched film
polySi


PR
PR
SiO2 ← Hard Mask
Stronger than PR against polySi etch
polySi
SiO2
polySi
Substrate

Microstructure Stiction

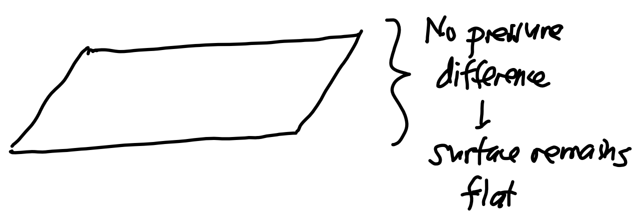
Surface Tension



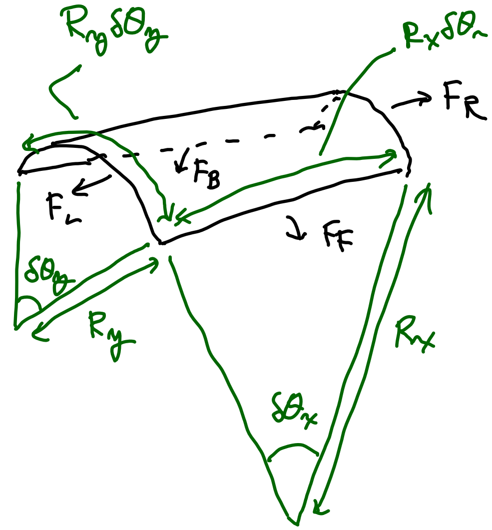
Equilibrium (nothing moves)
↳ forces balanced out by liquid's resistance to compression

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

Surface Curvature & Pressure



→ upon introduction of a differential pressure:
↳ surface curves to generate a net normal force that maintains equilibrium against the pressure



Young-Laplace Equation

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

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