Lecture 8: Surface Micromachining II

• Announcements:
  • HW#2 online & due Wednesday, 2/17, at 12 noon
  • There will be discussion tomorrow

• 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

• Last Time:
  • Going through a surface micromachining process in
    Module 5
  • Continue with this now
What if we want straight sidewalls?

- Case 3: $S_{PR} > S_{polysil} = 4:1$
  - $S_{PR} = 4:1$
  - $S_{polysil} = 2:1$
  - Fin oxide etch
  - PR etch (RIE)

- Case 2: $S_{PR} = S_{polysil} = 1:1$
  - $S_{polysil} = 1:1$
  - Fin oxide etch
  - PR etch (RIE)

- Case 1: $S_{PR} = S_{polysil} = 1:1$
  - $S_{polysil} = 1:1$
  - PR etch (RIE)

Because of the above selectivity, the sidewall of polysil and up being straight.

Oxide Hard Mask:

- Remove the polysil in PSG
- Heat to drive in dopants

Result:

- Symmetric doping – low stress

PSG Deposition

Microstructure Stiction:

Surface Tension

- Molecule @ liquid surface
  - Exponent and force
  - Liquid surface

Molecule under the liquid surface
  - Attractive forces from neighbors
  - Pulled in all directions
  - Net force is zero

Equilibrium -> nothing moves

- Force is balanced by the 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 tend 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 \( \Delta p \) = pressure difference
\( \gamma \) = surface tension
\( R_x \) and \( R_y \) = radii of curvature

Contact Angle:

- governed by a balance of surface tensions
- really a property dependent on the interface between different materials

Example: Hydrophilic Droplet

- \( f_{la} \) = liquid-air surface tension force
- \( f_{ls} \) = liquid-solid interface tension force
- \( f_A \) = adhesion force
- \( f_{sa} \) = solid-air surface tension force

Equilibrium:

1. Horizontal forces cancel
2. Vertical forces cancel at point

\[ f_A = f_{la} \cos \theta_c \]
\[ f_{sa} = f_{la} + f_{ls} \cos \theta_c \]

Relationship between surface tensions captured by \( \theta_c \).
Example: Two Plates Sandwiching Liquid

(cross-section)

\[ F = \frac{2\Delta \rho_a \cos \theta_c}{g} \]

Force needed to keep the plates apart

⇒ (1) force means negative Laplace pressure