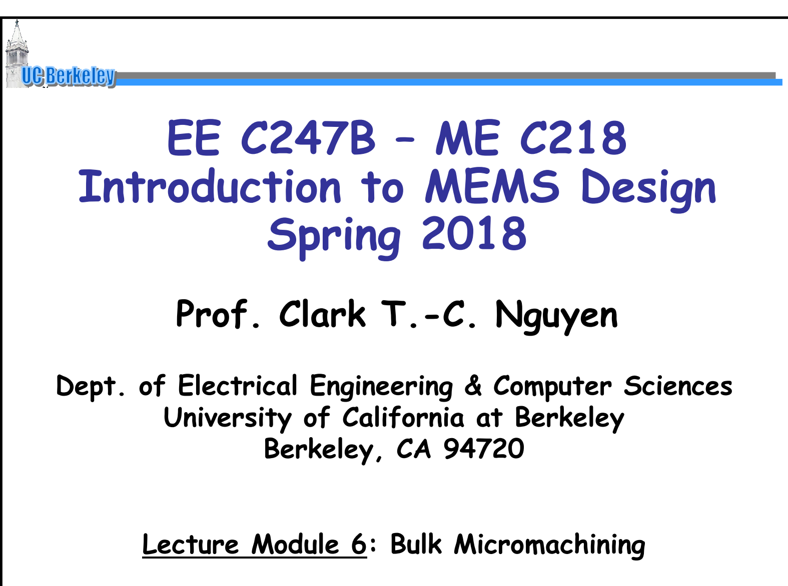

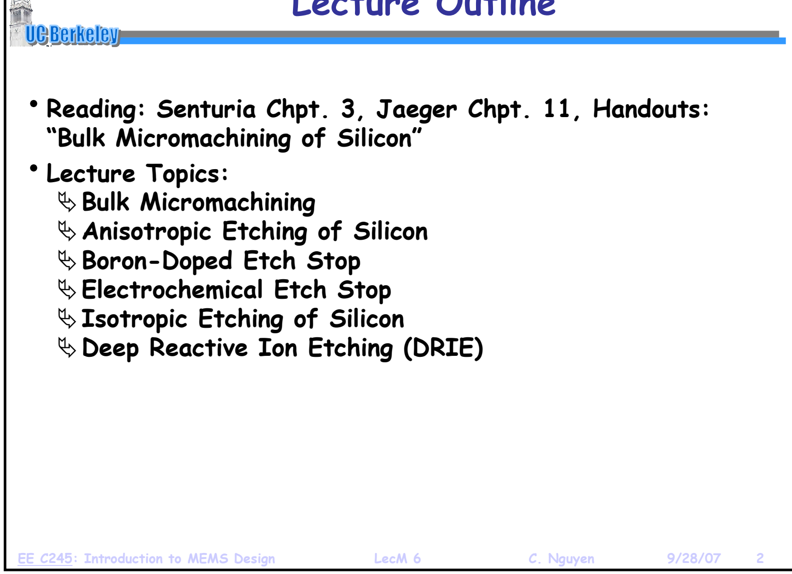

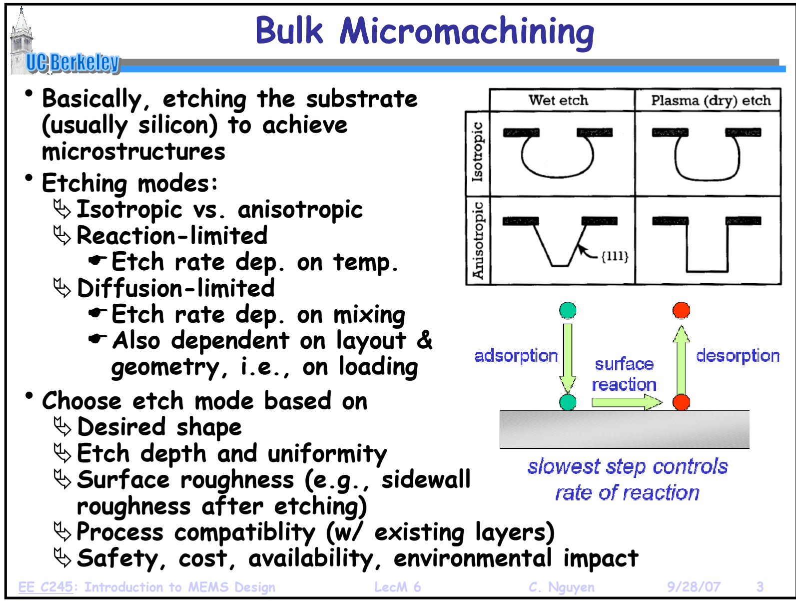

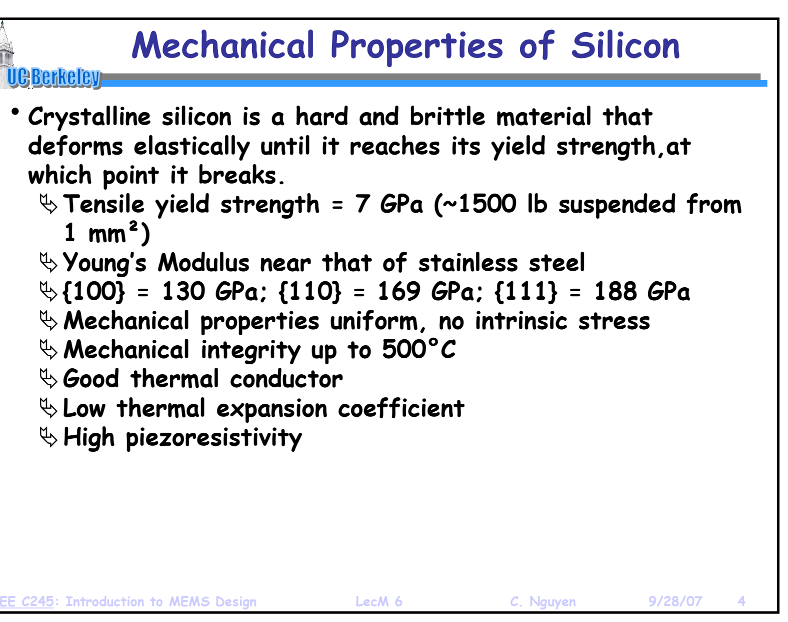

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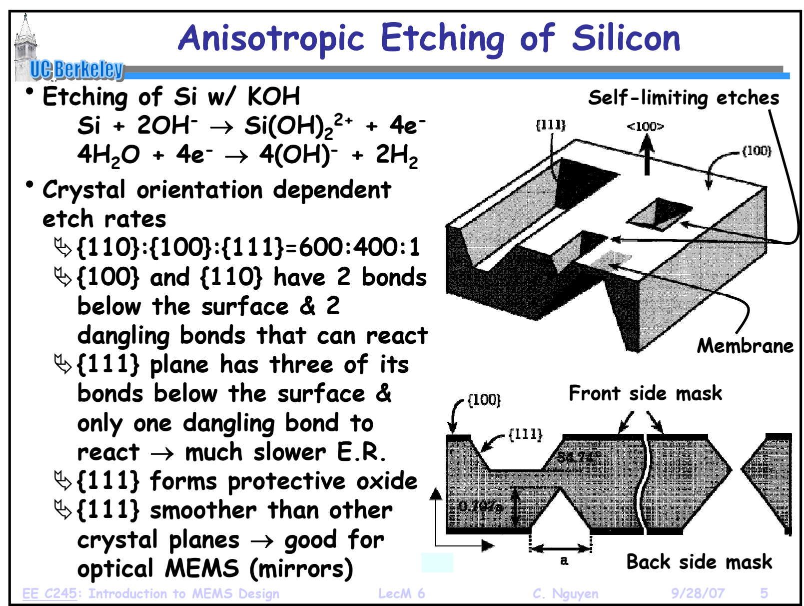

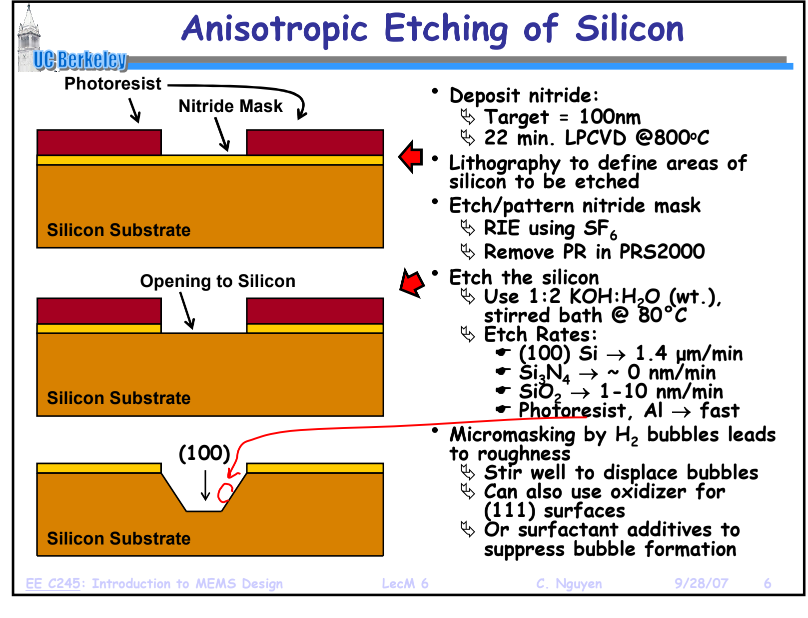

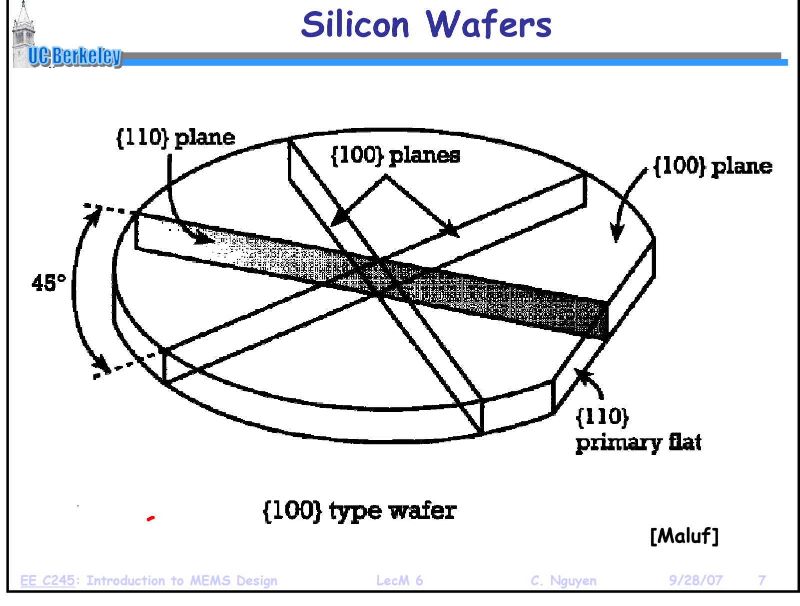

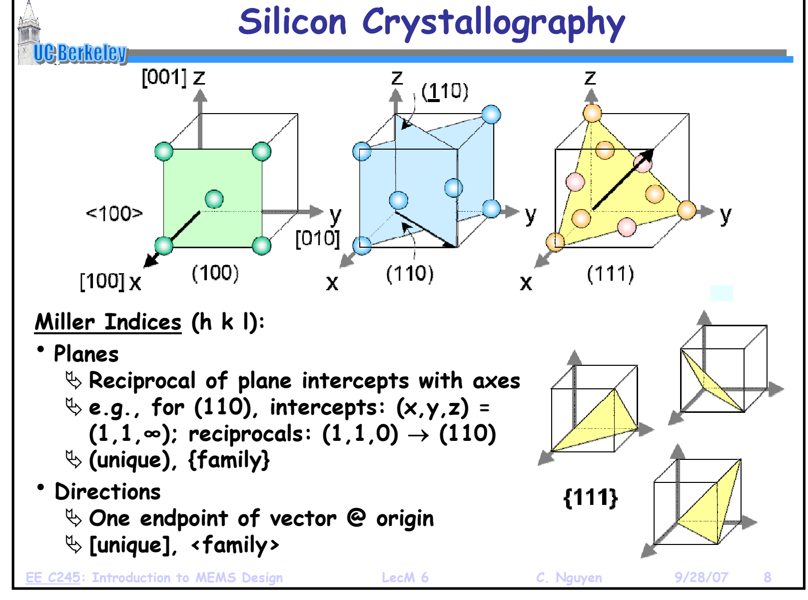

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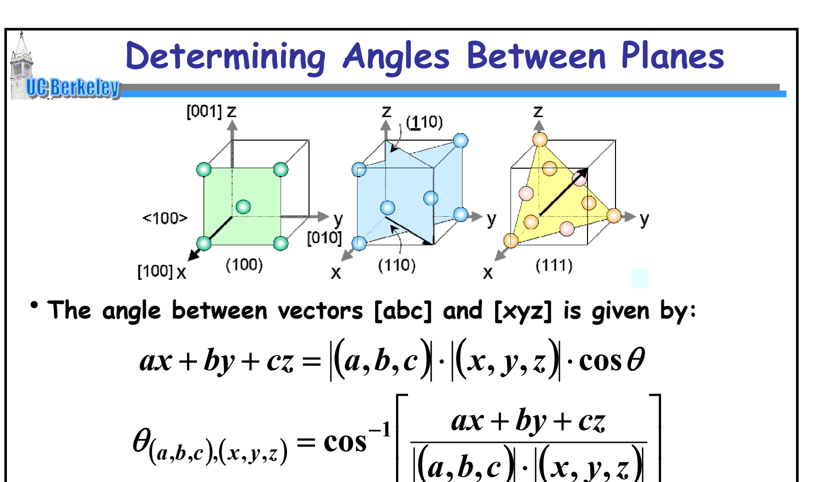
Determining Angles Between Planes



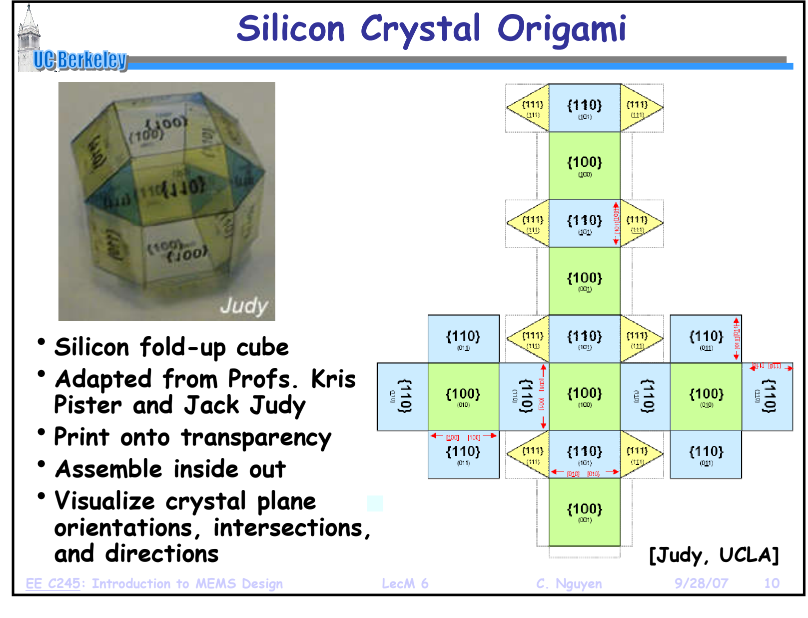
- The angle between vectors [abc] and [xyz] is given by:

$$ax + by + cz = \left|(a,b,c)\right| \cdot \left|(x,y,z)\right| \cdot \cos\theta$$

$$\theta_{(a,b,c),(x,y,z)} = \cos^{-1}\left[\frac{ax + by + cz}{\left|(a,b,c)\right| \cdot \left|(x,y,z)\right|}\right]$$

- For {100} and {110} → 45°
- For {100} and {111} → 54.74°
- For {110} and {111} → 35.26°, 90°, and 144.74°

Silicon Crystal Origami

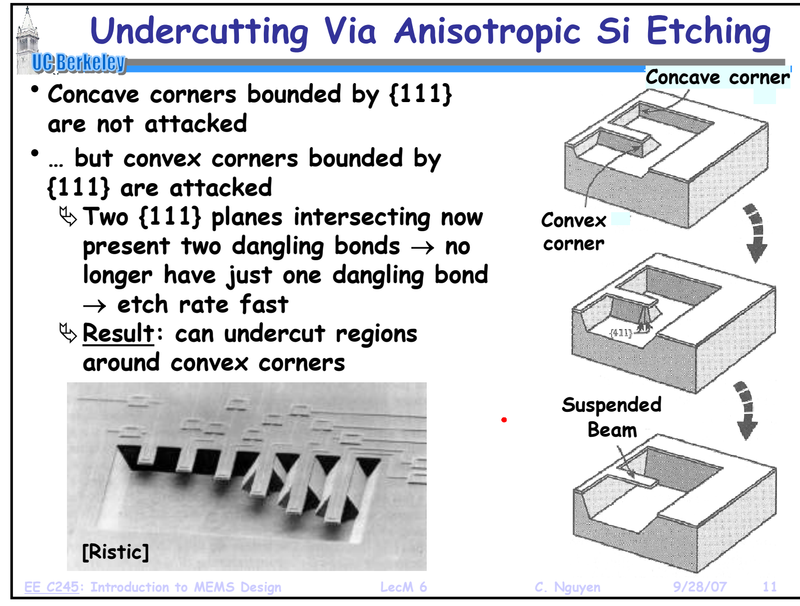


- Silicon fold-up cube
- Adapted from Profs. Kris Pister and Jack Judy
- Print onto transparency
- Assemble inside out
- Visualize crystal plane orientations, intersections, and directions

[Judy, UCLA]

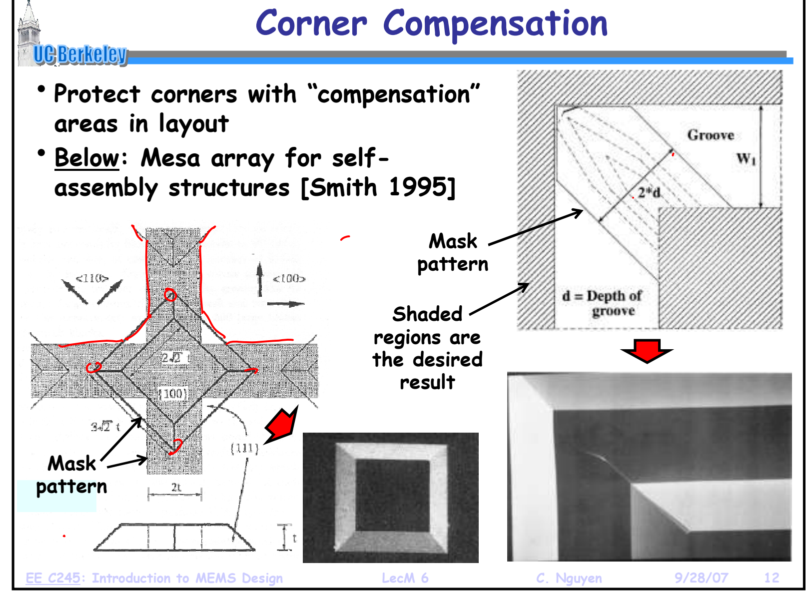
Undercutting Via Anisotropic Si Etching

- Concave corners bounded by {111} are not attacked
- … but convex corners bounded by {111} are attacked
  - Two {111} planes intersecting now present two dangling bonds → no longer have just one dangling bond → etch rate fast
  - Result: can undercut regions around convex corners



Corner Compensation

- Protect corners with "compensation" areas in layout
- Below: Mesa array for self-assembly structures [Smith 1995]



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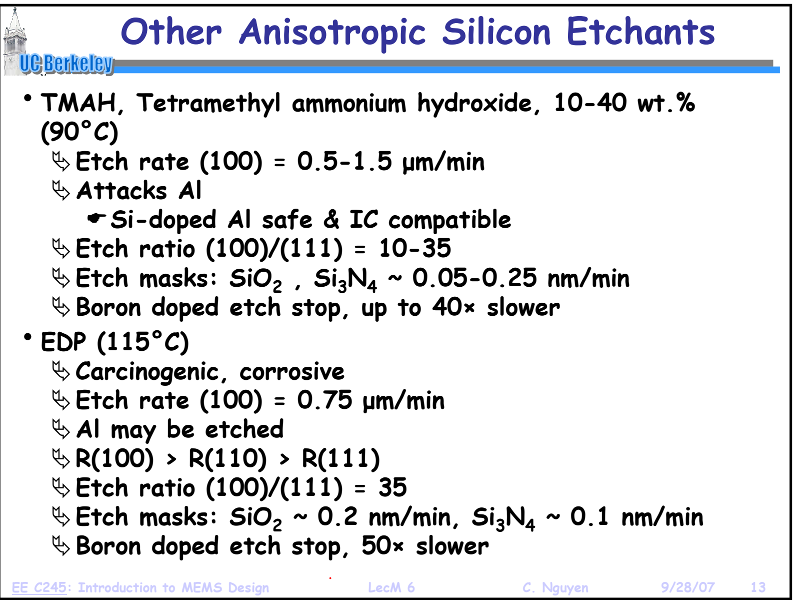

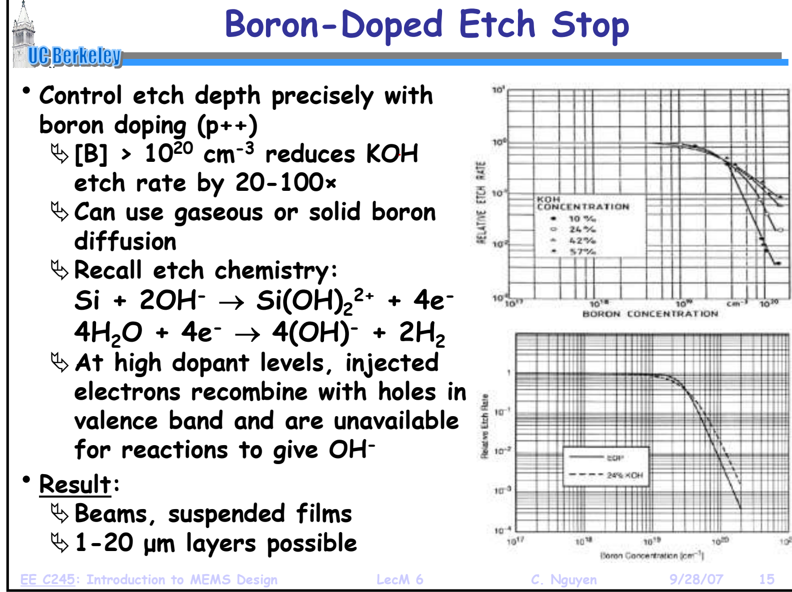

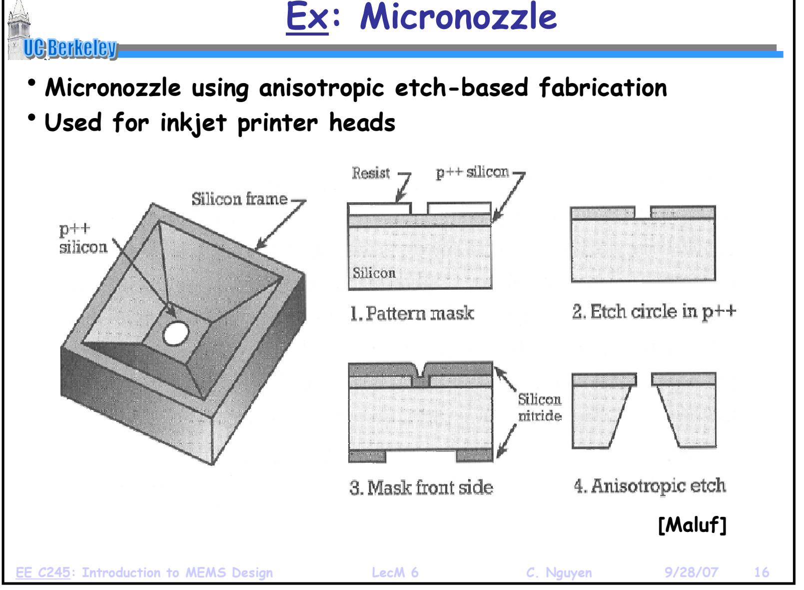

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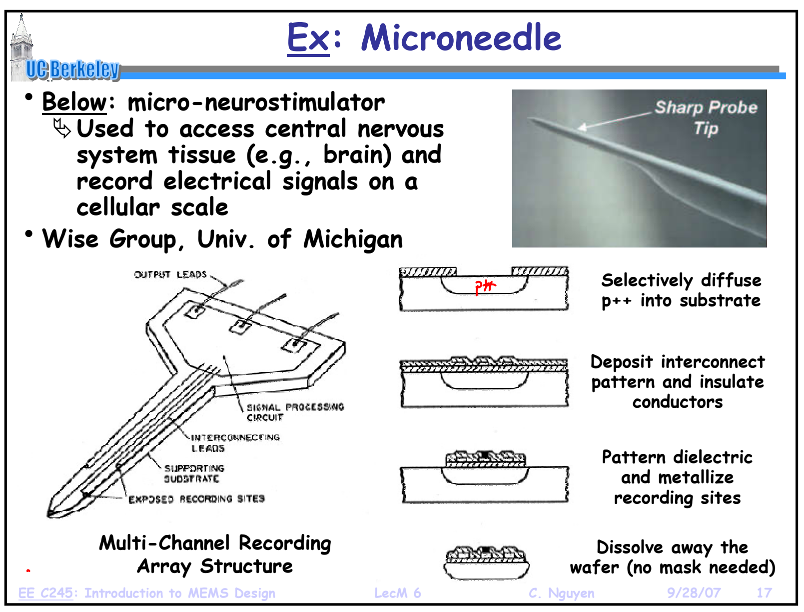

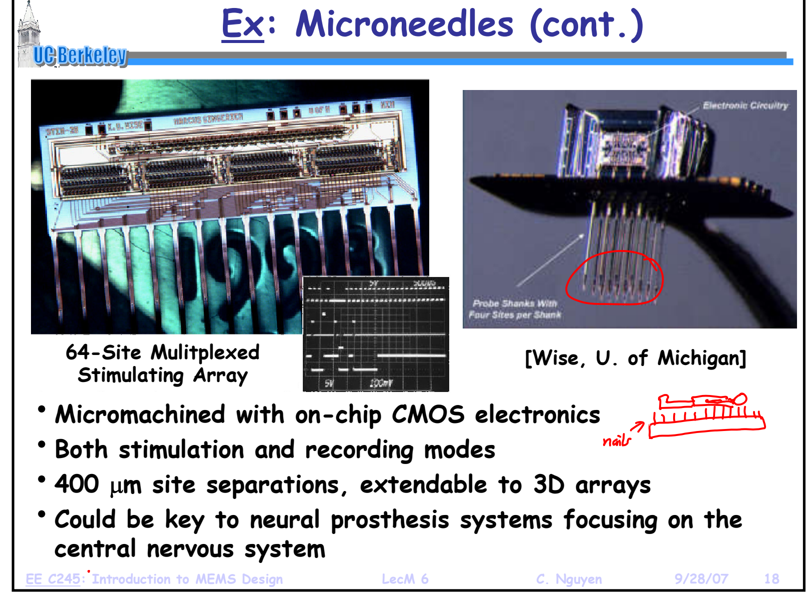

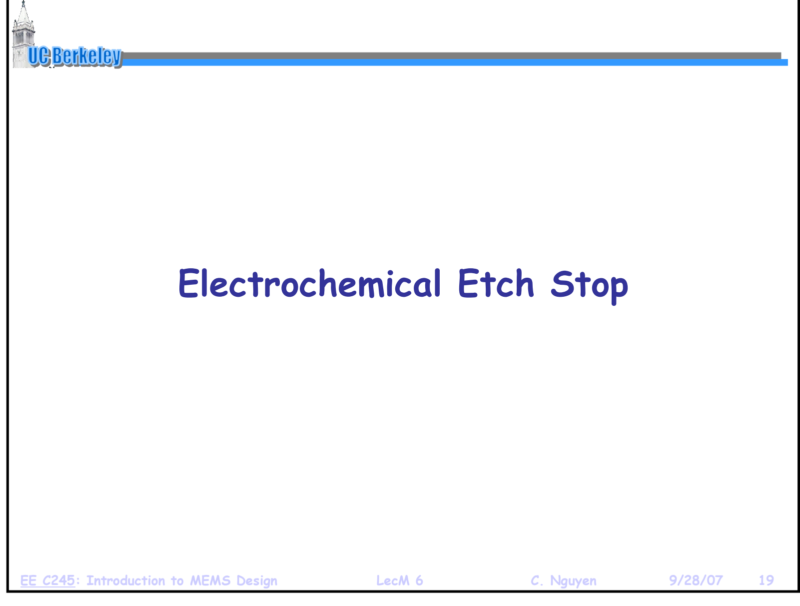

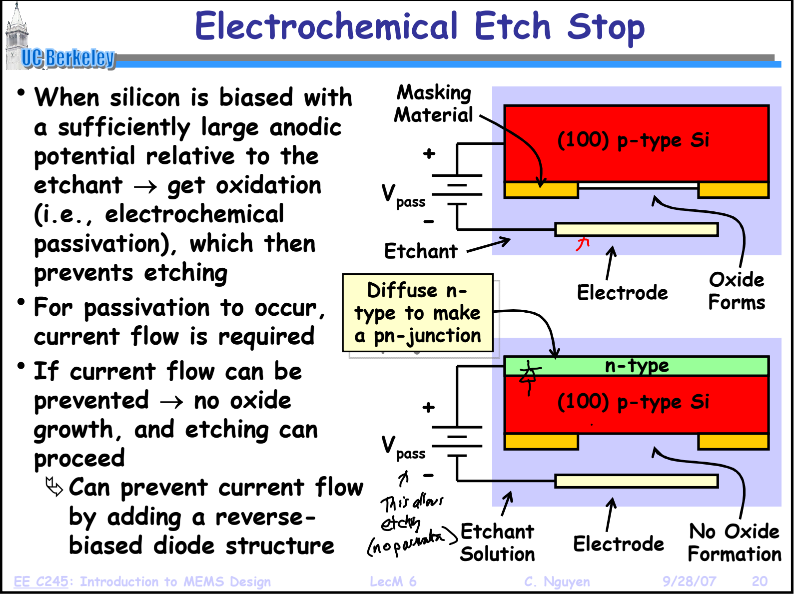

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Electrochemical Etch Stop

- Electrochemical etch stop
  - n-type epitaxial layer grown on p-type wafer forms p-n junction diode
  - $V_p > V_n \rightarrow$ electrical conduction (current flow)
  - $V_p < V_n \rightarrow$ reverse bias current (very little current flow)
- Passivation potential: potential at which thin SiO_2 film forms
  - different for p-Si and n-Si, but basically need the Si to be the anode in an electrolytic setup
- Setup:
  - p-n diode in reverse bias
  - p-substrate floating → etched
  - n-layer above passivation potential → not etched

p-Si
n-Si
OH⁻
electrode
oxide stop layer

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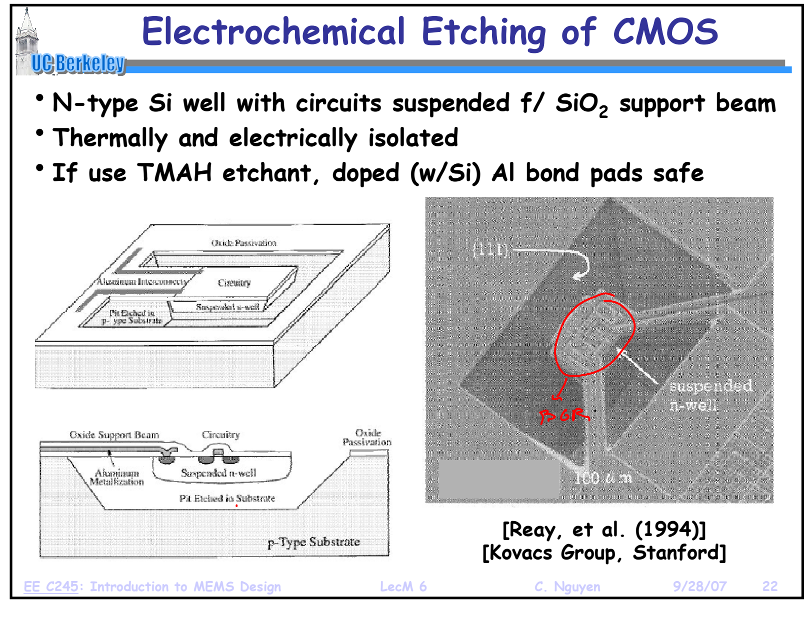

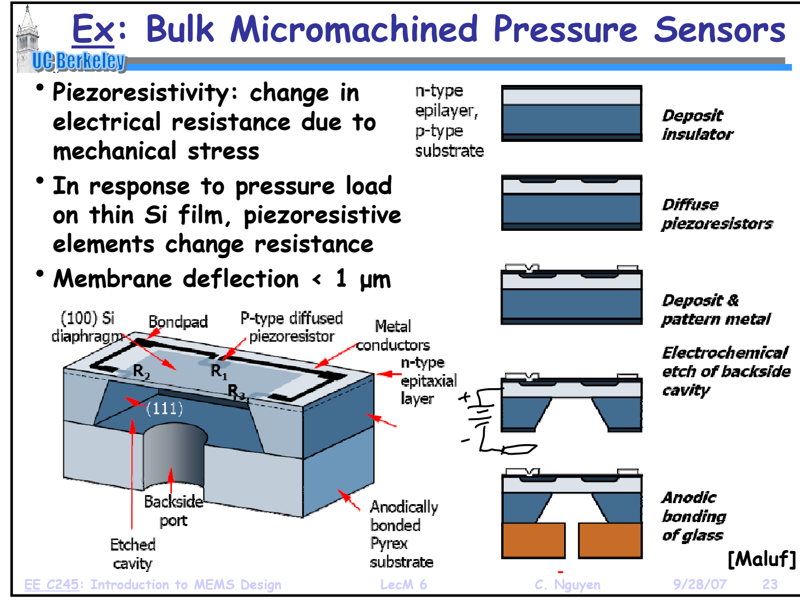

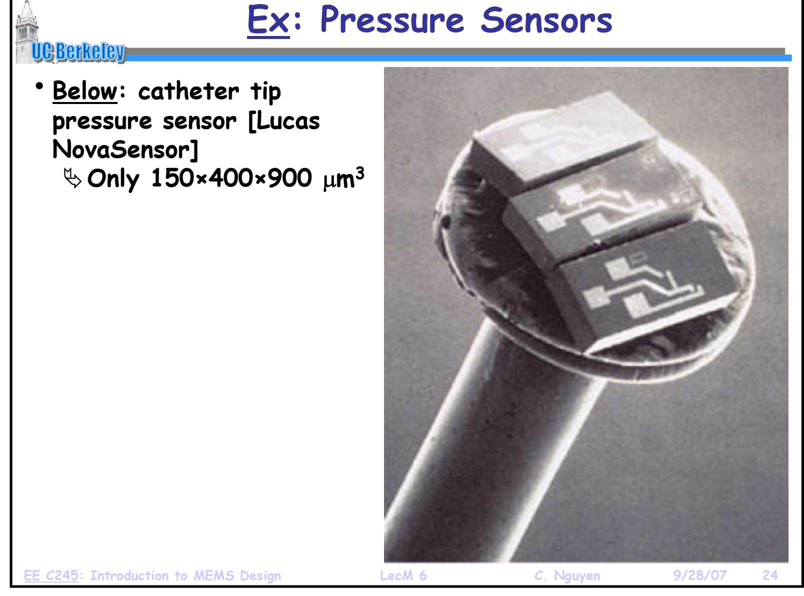

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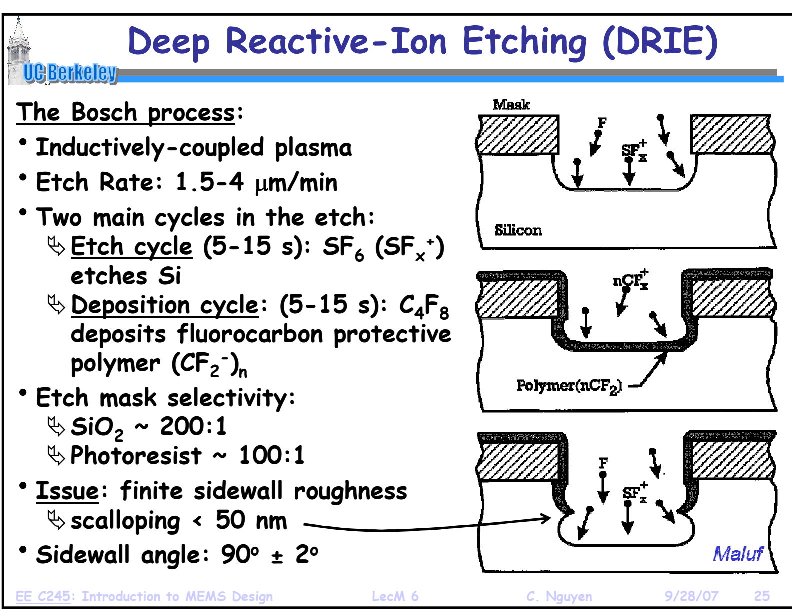

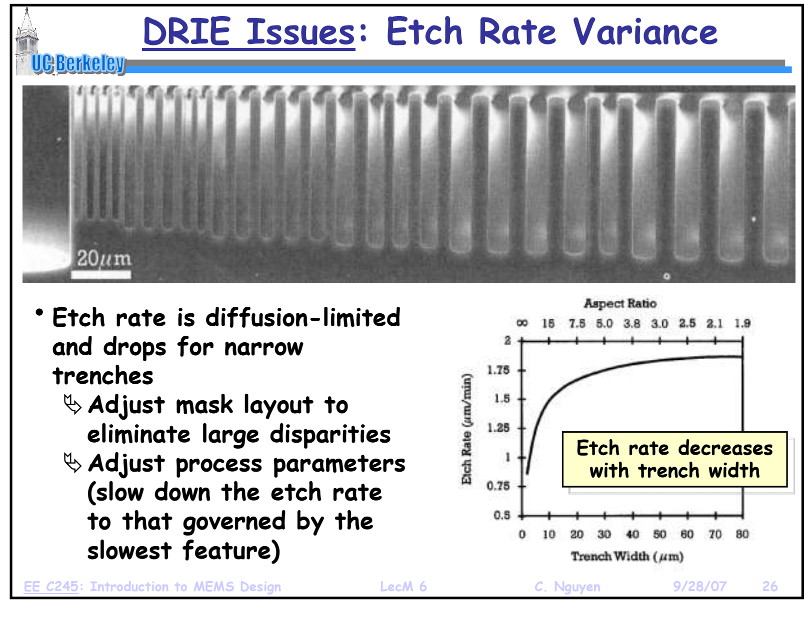

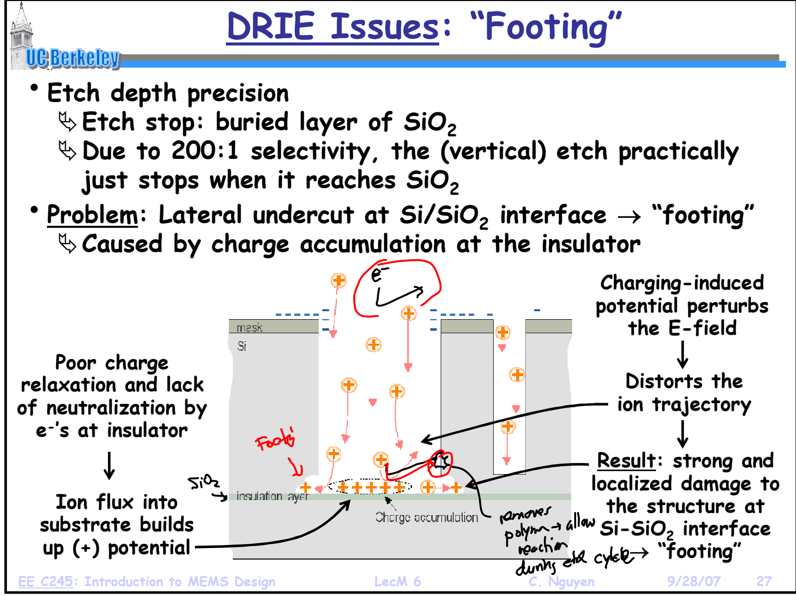

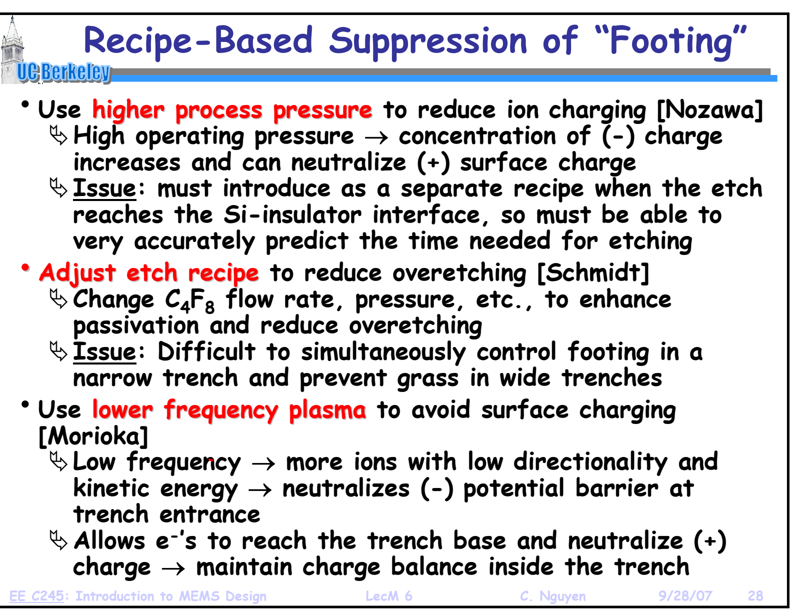

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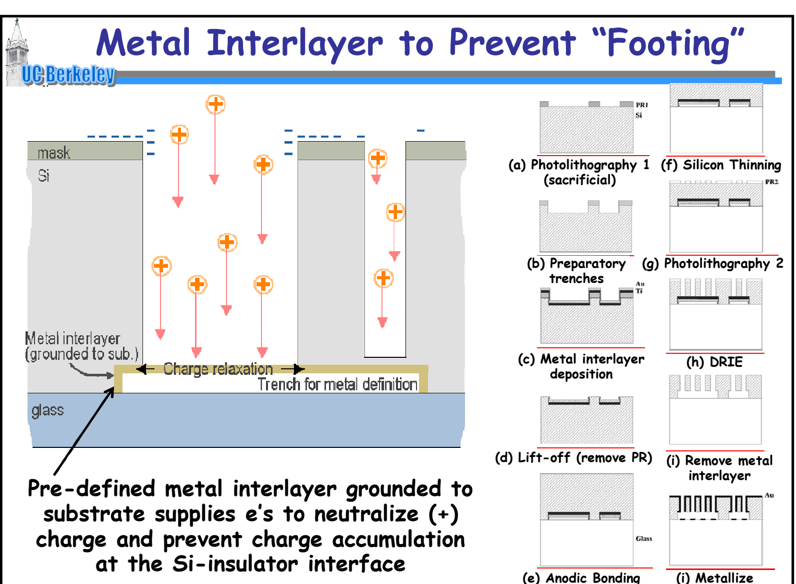

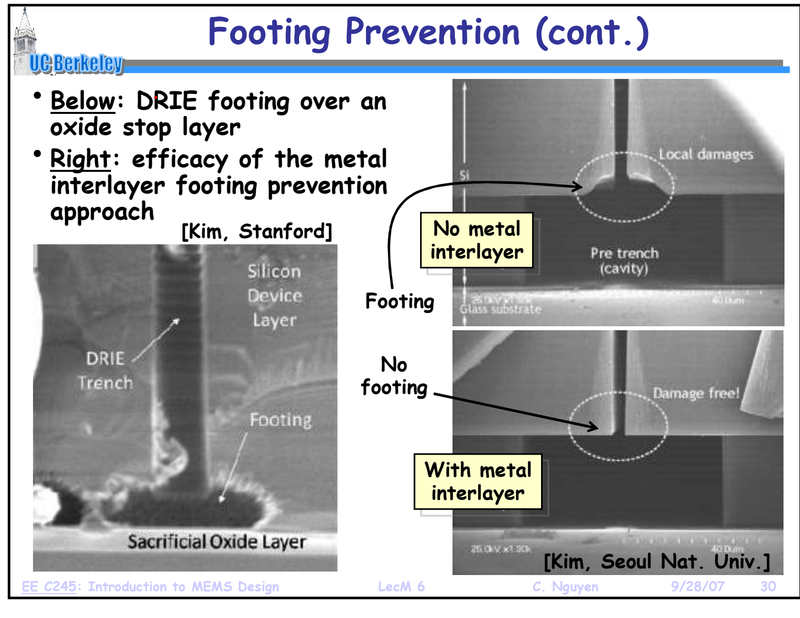

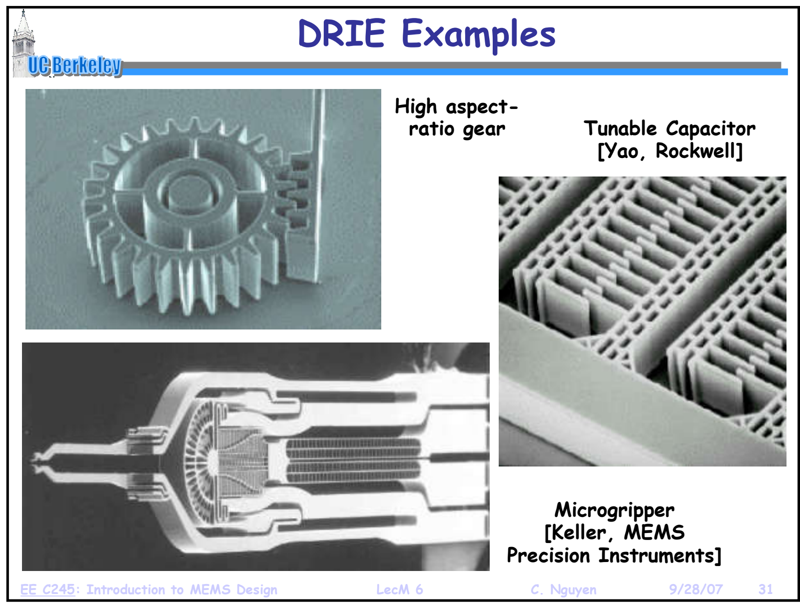

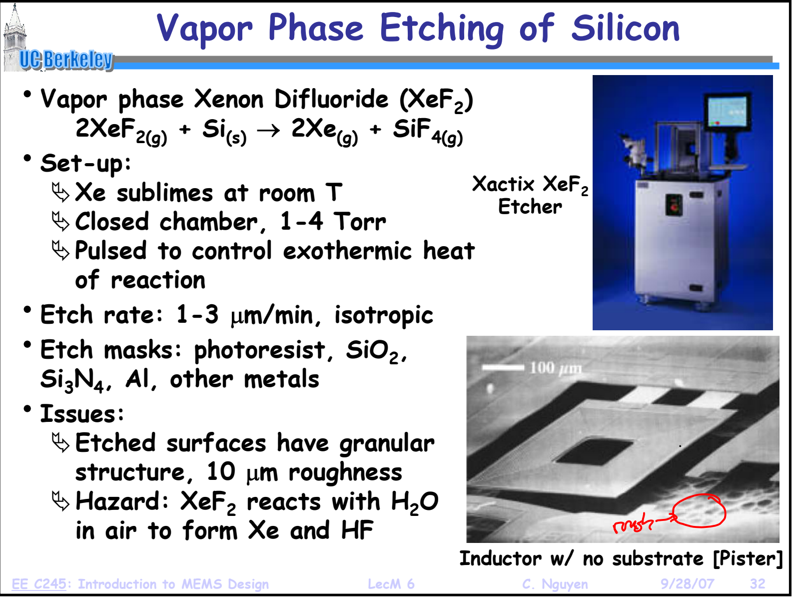

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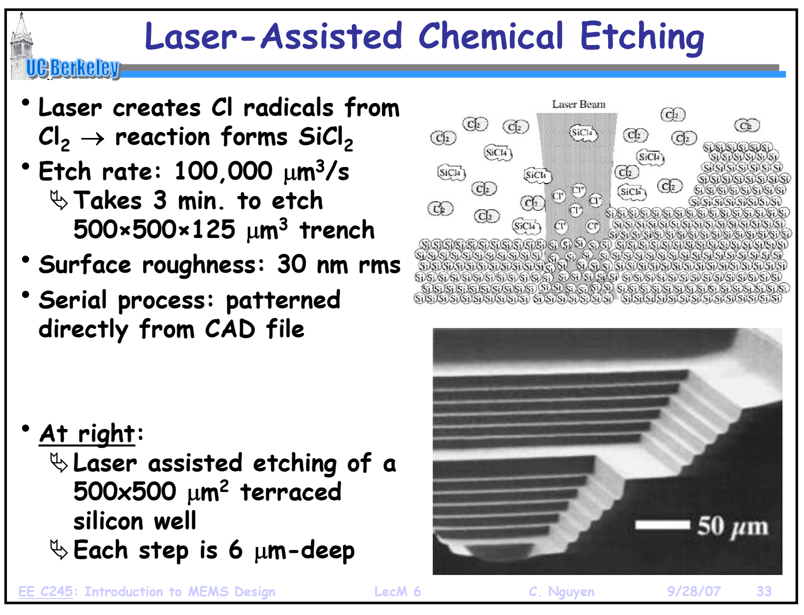

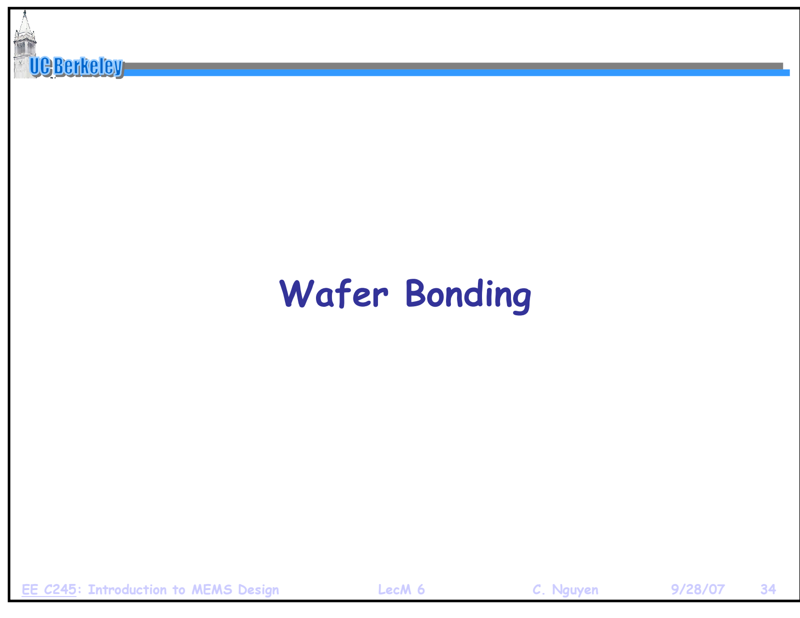

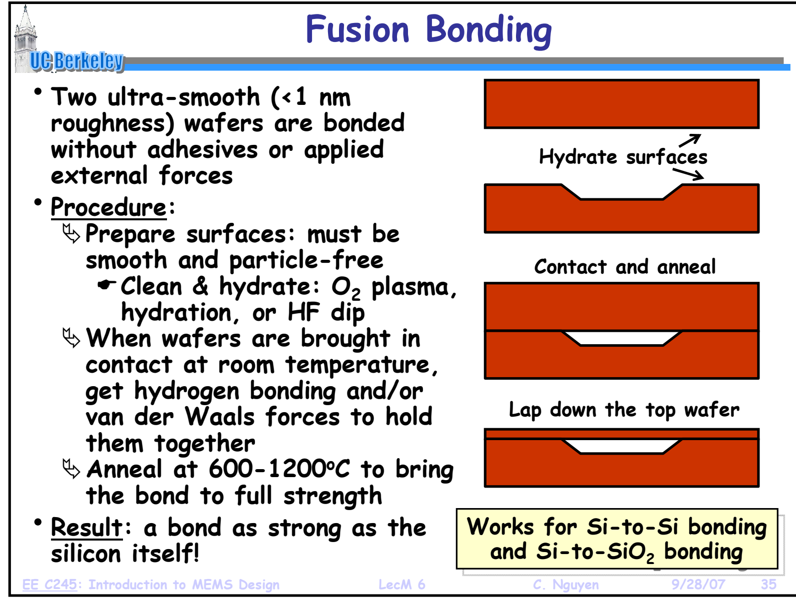

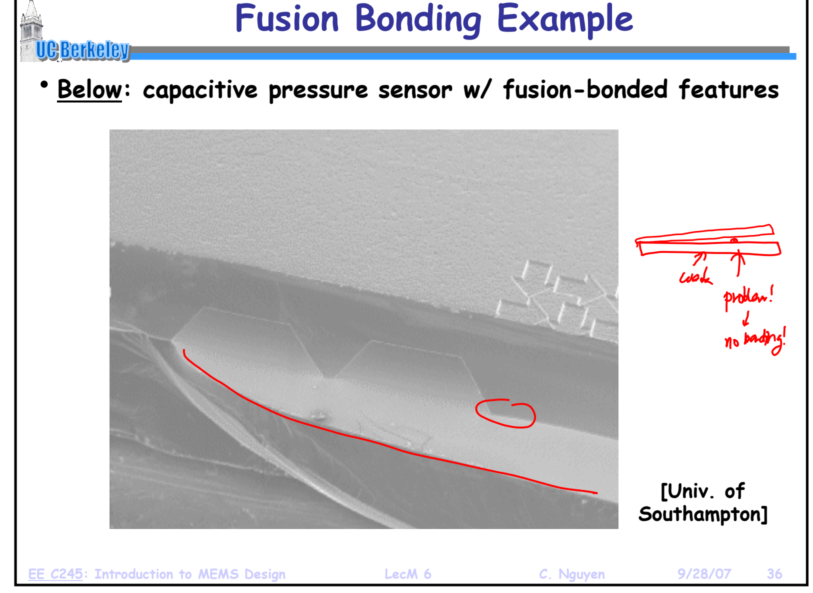

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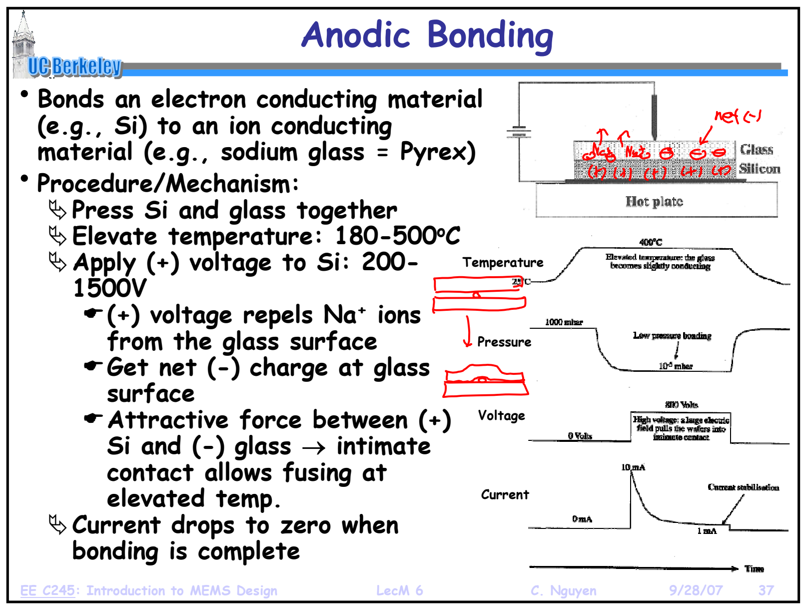

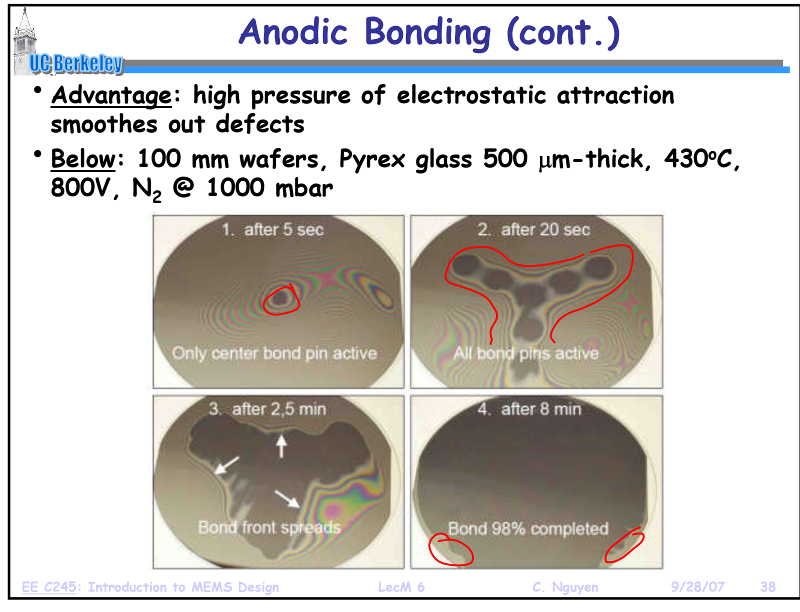

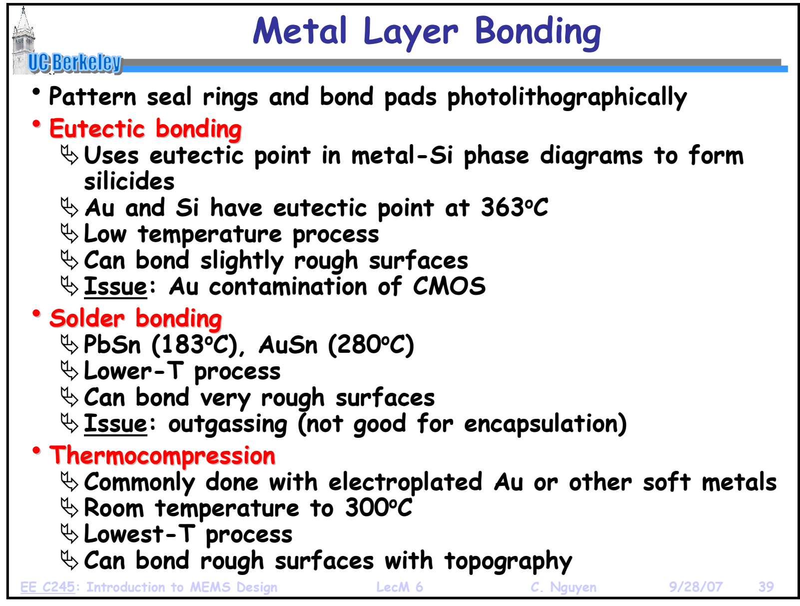

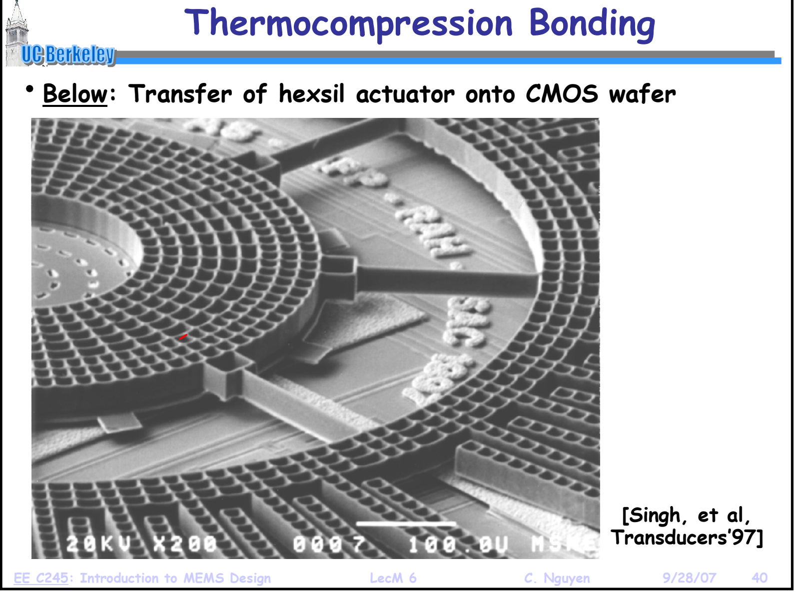

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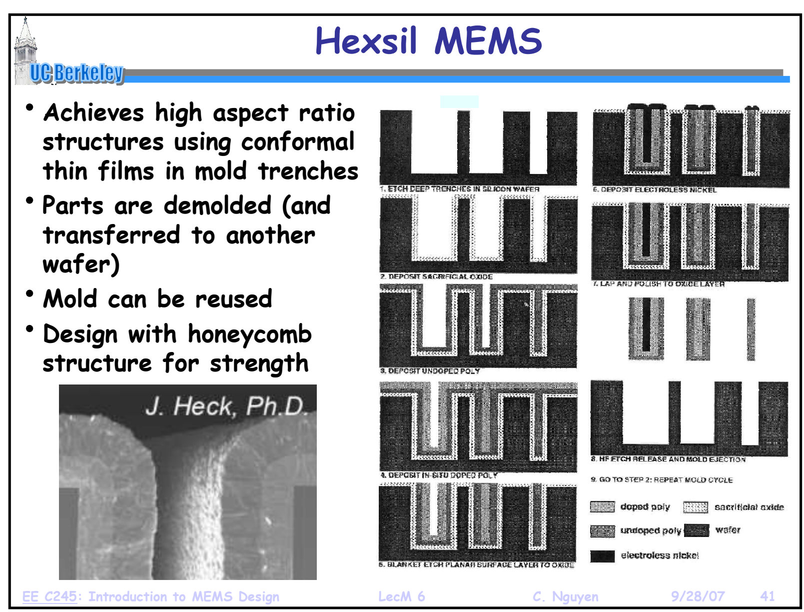

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