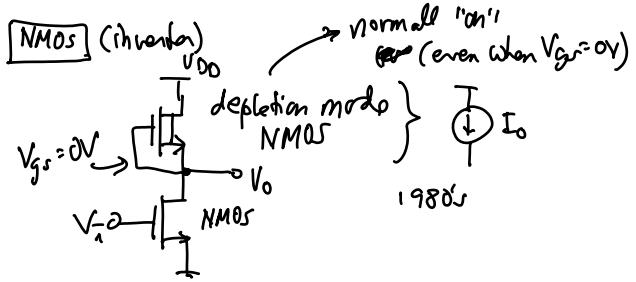
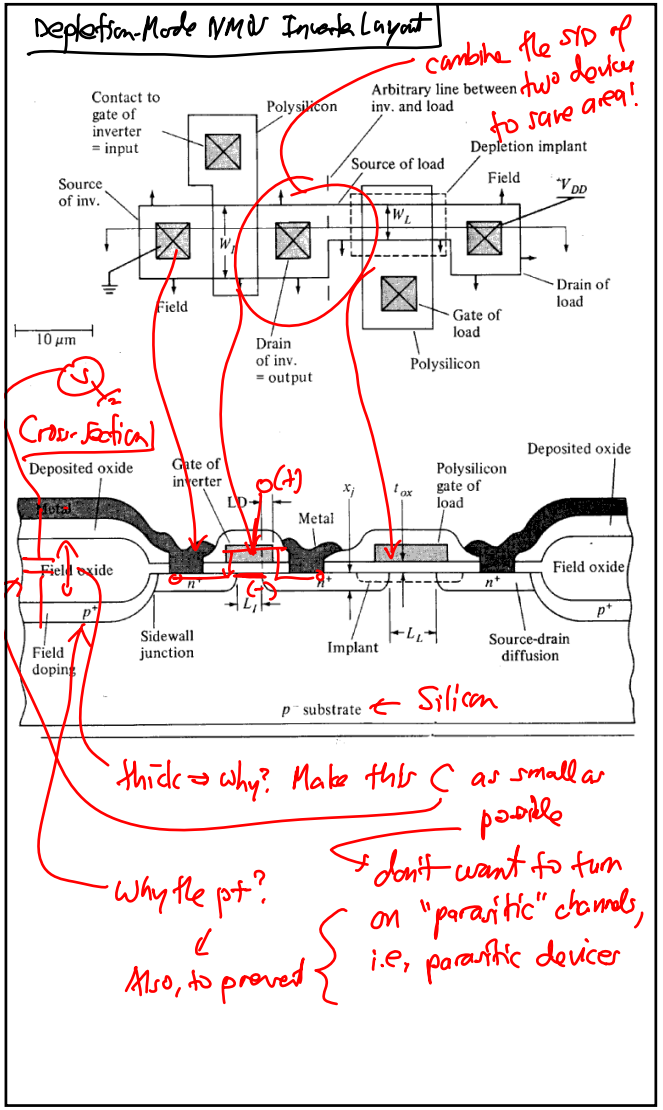
Announcements:

- Still 11 in lab section 101
  - needs to go down to 8
  - We'll let you sort it out until Monday, then will enforce a reduction on Tuesday
- Days that I will be traveling:
- Need to keep up with the syllabus for the labs
  - Next week Tuesday: Wei-Chang Li will be lecturing
  - Week after next: Feb. 1-5 – again, Wei-Chang will lecture
  - Recitation Classes?
- Search for recitation times:
  - No times; check later
- ----------
- Today: Finish IC History, start materials
- Lecture Topics:
  - Silicon
  - Silicon dioxide
  - Silicon nitride
  - Aluminum & other metals
- ----------
- Last Time: IC History





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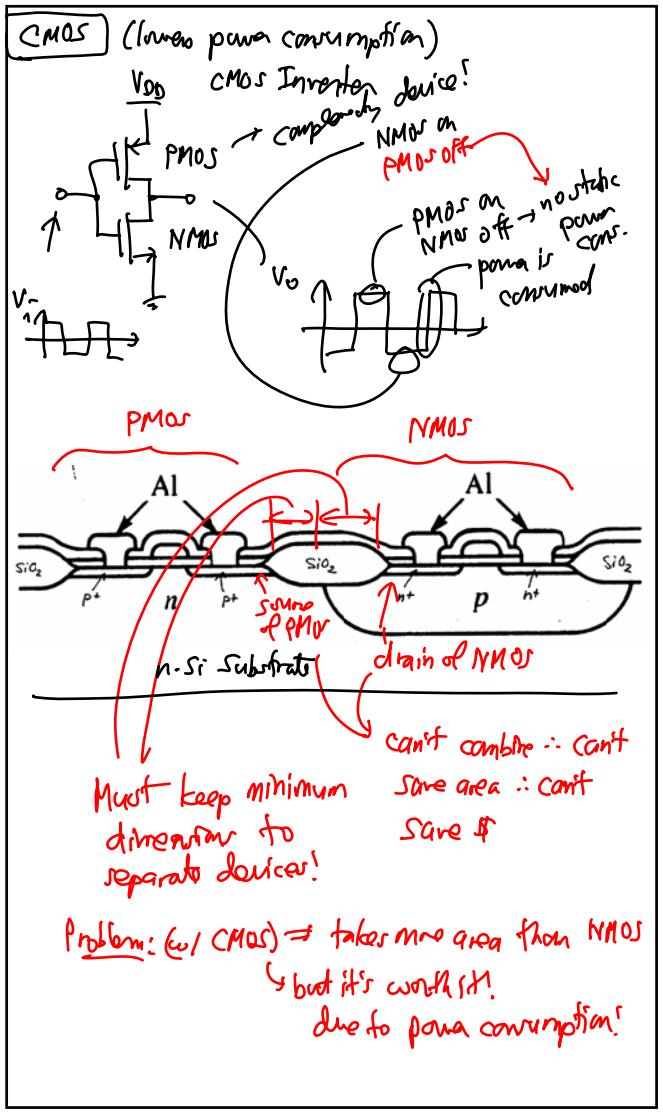

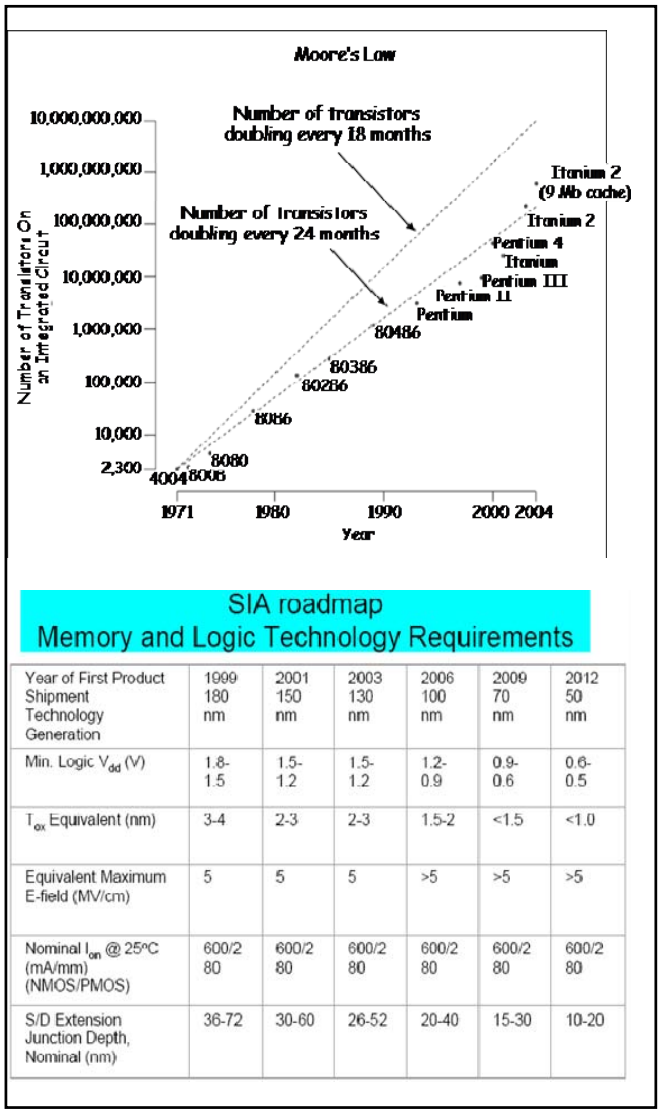

SIA roadmap
Memory and Logic Technology Requirements

Year of First Product Shipment	1999	2001	2003	2006	2009	2012
Technology Generation	180 nm	150 nm	130 nm	100 nm	70 nm	50 nm
Min. Logic V_{dd} (V)	1.8-1.5	1.5-1.2	1.5-1.2	1.2-0.9	0.9-0.6	0.6-0.5
T_{ox} Equivalent (nm)	3-4	2-3	2-3	1.5-2	<1.5	<1.0
Equivalent Maximum E-field (MV/cm)	5	5	5	>5	>5	>5
Nominal I_{on} @ 25°C (mA/mm) (NMOS/PMOS)	600/280	600/280	600/280	600/280	600/280	600/280
S/D Extension Junction Depth, Nominal (nm)	36-72	30-60	26-52	20-40	15-30	10-20

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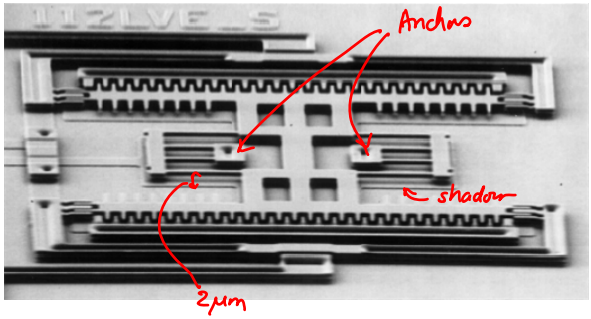
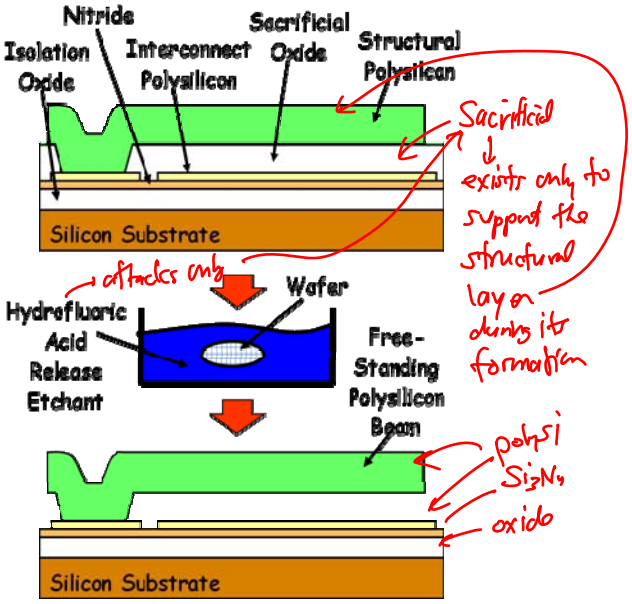
- Next in line: MEMS
  - Next step in the evolution of processing and integration
- Example: Micromechanical Resonator

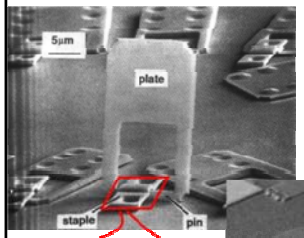




Sacrificial ↓ exists only to support the structural layer during its formation

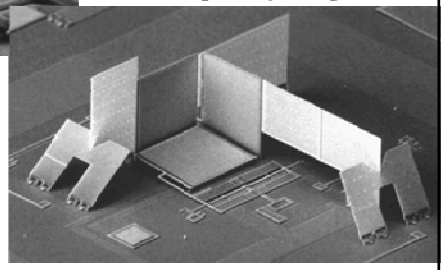
poly-Si
Si_3N_4
oxide

Kris Pister

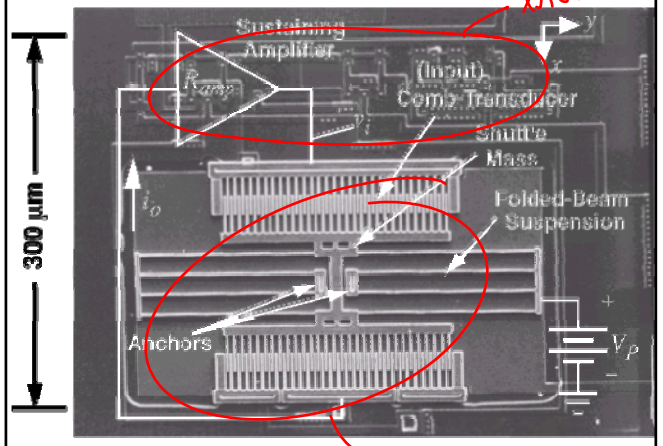


First MEMS hinge
[K. Pister, et al., 1992]

Corner Cube Reflector
[v. Hsu, 1999]



Fully-Integrated Timing Oscillator Based on MEMS



Resistors

MEMS

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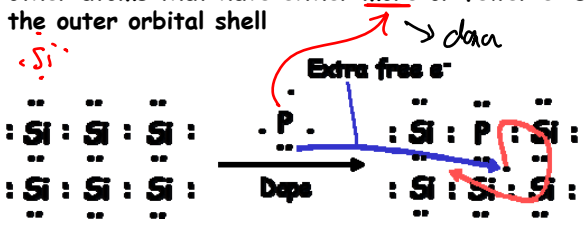
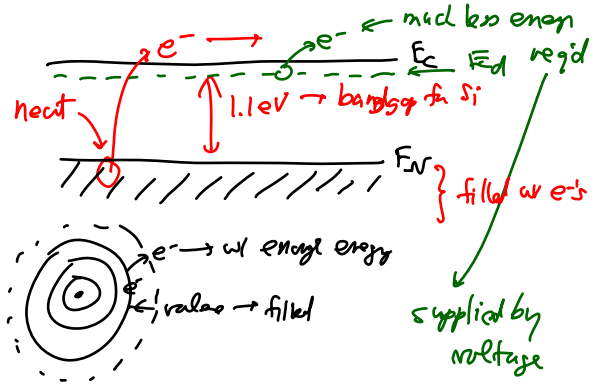
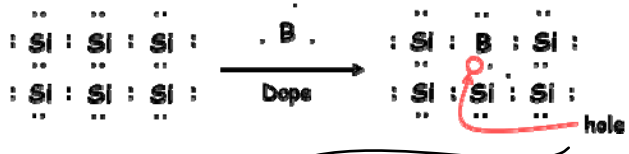
- Focus of this class: Silicon, but many of methods learned are also relevant to other materials, e.g., GaAs
- Materials in Silicon-Based Microfabrication:
  - (a) silicon
  - (b) silicon dioxide
  - (c) silicon nitride
  - (d) metals, such as Al or Cu, or silicidesFocus of this class: Silicon, but many of methods learned are also relevant to other materials, e.g., GaAs
- Other materials:
  - Tungsten, silicides, polyimides
- For each material, need to consider three items
  - Electrical characteristics
  - Chemical characteristics
  - Usage IC's
- ----------
- Silicon: single-crystal silicon
- Electrical: semiconductor
  - Can change its conductivity by introducing impurities, called dopants
- Semiconductors are not intrisincally conductive
- To make them conduct, replace Si atoms with other atoms that have either more or fewer e-'s in the outer orbital shell



- The larger the # of dopant atoms, the larger the number of free e-'s, so the higher the conductivity
- For those who understand band diagrams:



For an impurity w/ fewer e-'s than Si
→ acceptor



effectively mass, so system can conduct

Conductivity Equation

$\sigma = q\mu_n n + q\mu_p p$

- σ: conductivity
- q: charge on an e⁻
- μ_n: electron mobility
- n: electron density
- μ_p: hole mobility
- p: hole density

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