Lecture 7: Surface Micromachining I

- Announcements:
  - HW#1 due Wednesday, 2/10, at 12 noon
  - Module 5 on “Surface Micromachining” online

- Today:
  - Reading: Senturia, Chpt. 3; Jaeger, Chpt. 2, 3, 6
  - Lecture Topics:
    - Diffusion
    - Ion Implantation
  - 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 Module 4 (“Lithography, Etching, and
    Doping”) diffusion
  - Continue with this now

---

**Ion Implantation**

- A more accurate way to introduce dopants below
  1. Accelerate B+ ions into the Si-substrate
  2. B+ punches into the Si
  3. Raise T to move the B into the lattice only when
     it’s in the lattice for a sufficient time
  4. Keep T up to drive the dopants in to the desired depth.

**Advantages:**

1. Accurate dose
2. Change depth by setting ion energy
3. No need for high temperature - anneal can be a
   rapid thermal anneal (RTA)
Problem: COST!

An ion implant is quite a sophisticated piece of equipment! → and expensive! (> $1 million)

B+ gas → plasma

B₂H₆ → B₂H₄ + B₂ +

B₂H₅ + B +

B+ gas then accelerate it into the wafer!

This takes intricate tuning.

Energy Range: 20 keV - 100 keV

Penetration Depth: fraction of a μm

- Larger ions don't go as far as smaller
  (heavier ions penetrate shallower than smaller)

Doze: 10¹¹ - 10¹² cm⁻²

Now, start going through Module 5 on Surface Micromachining

- 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 reliability 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
What if we want straight sidewalls?

- PR edge mover
- $\text{Si}_2$ (hard mask)
- polysilicon
- $\text{Si}_2$
- Substrate

Final $\text{Si}_2$ sidewalls are sloped!
(transformed some of the PR stage to the $\text{Si}_2$)

Final slope depends on etchant selectivity.

$\text{Si}_2^\text{PR} \leftarrow$ longer $\rightarrow$ smaller stage in $\text{Si}_2$

(assumed anisotropic etching)

Actual PR will be slightly sloped

If want sloped sidewalls, slope the PR $\rightarrow$ can do this by overexposing it.