Lecture 6: Process Modules II

- **Announcements:**
  - HW#2 will be online soon
  - Lecture Modules 3 & 4 on Process Modules online
  - Process Module Details lecture videos online
    - Lecture 7.x
    - These give more details than I will give in class
    - Watch these if your background in microfabrication is weak
      — Very helpful for homework (& research)

- **Today:**
  - Reading: Senturia, Chpt. 3; Jaeger, Chpt. 2, 3, 6
  - Lecture Topics:
    - Example MEMS fabrication processes
    - Photolithography
    - Etching
    - Oxidation
    - Film Deposition
    - Diffusion
    - Ion Implantation

- **Last Time:**
  - Just finished etching in Module 2
  - Now continue with oxidation

- **Anisotropic Etchant Examples:**
  - Reactive ion etch
  - Ion milling
  - Square profile for undercut

- **Remarks:**
  - Wet etching is fairly cheap
  - Dry etching requires a plasma, so requires some expensive equipment
  - Don't always want straight sidewalls
Remarks:
- Uniformity can be better than 2\% across the wafer from lot to lot.
- Need to flow the O\(_2\) fairly fast in order to minimize reactant losses from the first boat to the last one.

Thin-Film Deposition:
- For deposition of films like Al (and other metals), SiO\(_2\), Si\(_3\)N\(_4\), and polysilicon.
- Deposition, not thermal growth.

**Example: Evaporation**

- Wafer
- Up temperature
- Al evaporates
- Hang Al substrate

**Example: Sputtering**

- Target (e.g., Al, SiO\(_2\), Si\(_3\)N\(_4\), W)
- A\(_2\)+ plasma cloud of charged particles (ions)
- Accelerated by an E field
- Deposit particle on target and randomly (sputter)

- Also, have chemical vapor deposition (CVD)
  - Chemical reaction involved in deposition of a given thin film.
  - High temperature, but not nearly as high as often required for thermal growth.

**Chemical Vapour Deposition**

- Heating coil element
- Standing wave
- Si(\text{silane})
- Chemical decomposition to deposit polysi

@ 400\(^\circ\)C not conformal

- Remarks:
  - Lot's of materials can be deposited in a similar manner: polysilicon, SiO\(_2\), Si\(_3\)N\(_4\), tungsten.
  - Compared to sputtering, CVD is less expensive since one can coat many wafers at once; sputtering generally does it one at a time.
  - For higher temperature, CVD films are much more conformal than sputtered films.
- Go through Module 4, slides 48-50, on Semiconductor Doping

- Diffusion:
  - Process of introducing dopants into selected areas on an IC
  - Example:
    - B$_2$H$_6$ + O$_2$ @ high temperature ≈ 800°C - 1200°C
    - Form borosilicate glass w/ high B concentration.
    - Boron diffuses in → this becomes p-type

=> Diffusion requires:
  1. concentration gradient
  2. movement (velocity)

- Example: Fish Tank
  1. When separate removed...
  2. Fish will go to the other side
  3. Until the concentration is the same on both sides
  But they can't if they're dead!
It's similar to an impurity in silicon:

1. **Vacancy** must exist.
2. The B must have enough energy to move.
   - High temperature is required to induce diffusion of impurities in Si!

Definitions:
1. **Predeposition**: diffusion with dopant source present
2. **Drive-in**: diffusion in an inert ambient, e.g., N₂ with no dopant gases present.

- Go through Module 4, slides 65-81, on Diffusion Modeling and Sheet Resistance
Ion Implantation

- a more accurate way to introduce dopants before drive-in

1. Accelerate B⁺ ions into the Si-substrate
2. Make layer (e.g., oxide) on PR
3. B⁺ punches into the Si band
4. Raise T to move the B into the lattice - only when it's in the lattice is it active & can contribute to the doping level
5. Keep T up to drive the dopants into the desired depth.

Advantages:
1. accurate dose
2. change depth by setting ion energy
3. no need for high temperature

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

B⁺ gas → plasma → B₂H₆ → B₂H₆⁺, B⁺
     → B₂H₅⁺ B⁺
     → B⁺
     → water
     → This takes intricate tuning.

Energy Range: 20 keV - 100 keV
Penetration Depth: fraction of a μm
   → large ions don't go as far as smaller (heavier ions penetrate shallower than smaller)
Dose: 10¹¹ - 10¹⁵ cm⁻²

Now, start going through Module 5 on Surface Micromachining