Lecture 6: Process Modules II

- **Announcements**:
- HW#2 online
- Lecture Modules 3 & 4 on Process Modules online
- Process Module Details lecture videos online
  - These give more details than I will give in class
  - Watch these if your background in microfabrication is weak
    - —Very helpful for homework (& research)
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- **Today**:
- Senturia, Chpt. 3; Jaeger, Chpt. 2, 3, 6
  - Example MEMS fabrication processes
  - Photolithography
  - Etching
  - Oxidation
  - Film Deposition
  - Diffusion
  - Ion Implantation
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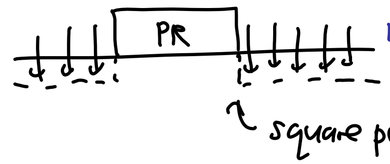
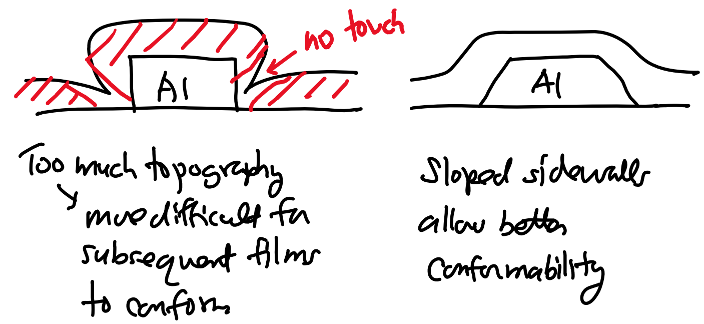
- **Last Time**:
- Going through etching in Module 4
- Now, continue with this …

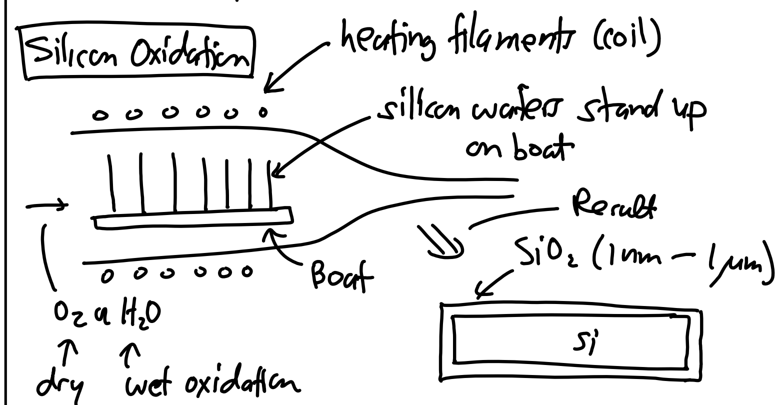
- Anistropic Etchant Examples:
  - Reactive ion etch
  - Ion milling

  } Use ions under E-fields to give the etch more directionality.



- Go through Module 4, slides 15-21, 36-47
- **Remarks**:
  - Wet etching is fairly cheap
  - Dry etching requires a plasma, so requires some expensive equipment
  - Don't always want straight sidewalls

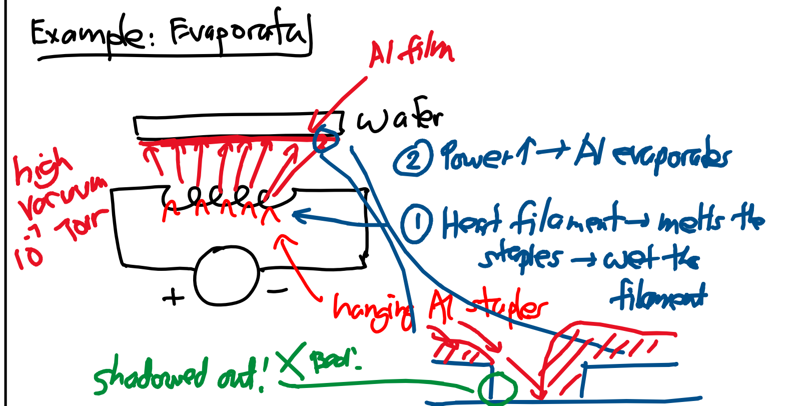


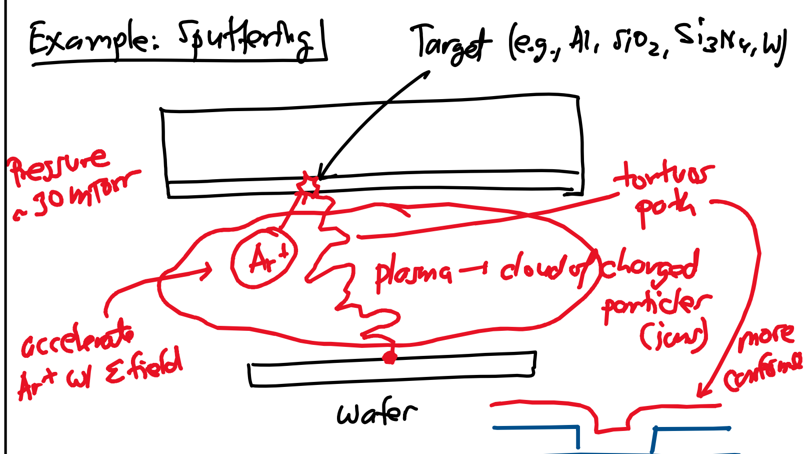


- **Remarks**:
  - Uniformity can be better than 2% across the wafer from lot to lot
  - Need to flow the O_2 fairly fast in order to minimize reactant losses from the first boat to the last one

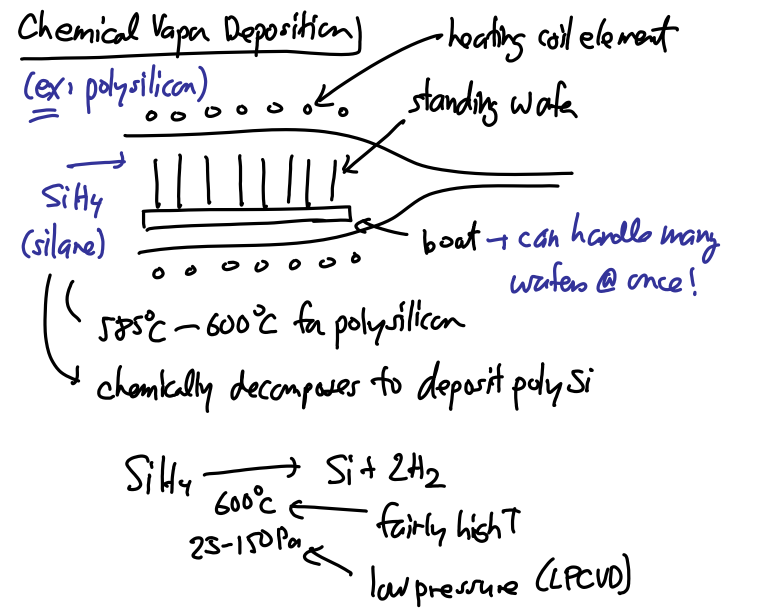
Thin-Film Deposition:

- For deposition of films like Al (and other metals), SiO_2, Si_3N_4, and polysilicon
- Deposition, not thermal growth

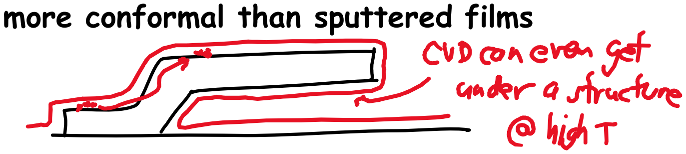




- Also, have chemical vapor deposition (CVD)
  - Chemical reaction involved in deposition of a given thin film
  - High temperature, but not nearly as high as often required for thermal growth



- **Remarks**:
  - Lot's of materials can be deposited in a similar manner: polysilicon, SiO_2, Si_3N_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

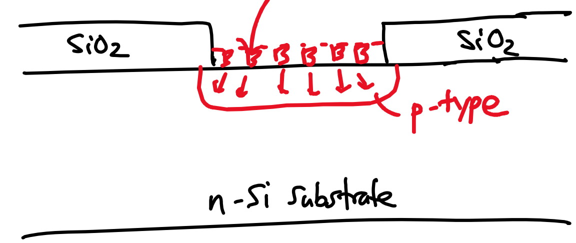


- Go through Module 4, slides 48-50, on Semiconductor Doping

- **Diffusion**:
- Process of introducing dopants into selected areas on an IC
- **Example**:

Borosilicate Glass

diborone gas → $B_2H_6 + O_2$ @ high temperature ~ 800°C — 1200°C



① Form borosilicate glass w/ high B concentration

② Boron diffuses in → this becomes p-type

⇒ diffusion requires:

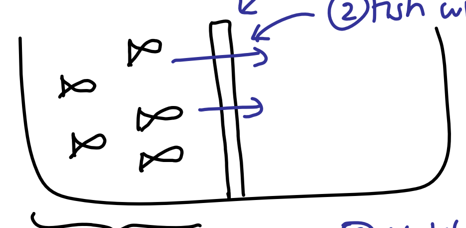
① concentration gradient

② movement (velocity)

→ Example. Fish Tank

① When separator removed..

② Fish will go to the other side

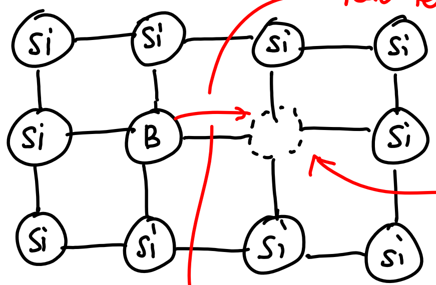


highly concentrated

③ Until the concentration is the same on both sides

But they can't if they're dead!

It's similar for an impurity in silicon:



need temperature for this to happen

Need higher T for this vacancy to exist.

Just one mechanism for diffusion → we'll look at others, too

Substitutional diffusion:
⇒ impurity moves along vacancies in the lattice
⇒ substitutes for a Si atom in the lattice

For movement to occur:

① Vacancies must exist.
② The B must have enough energy to move.

} Both require high temperature!

→ must heat to induce diffusion of impurities in Si!

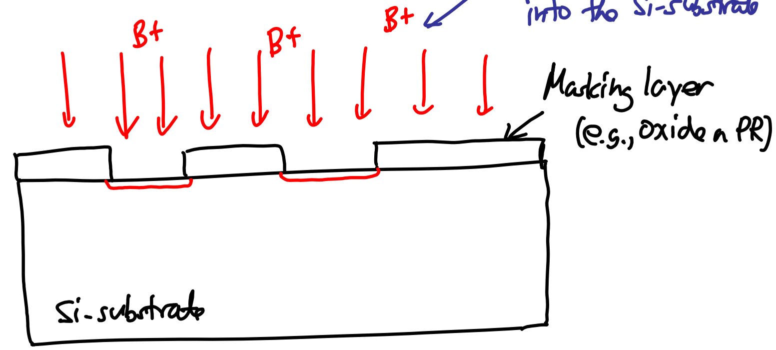
Definitions:

① Predeposition: diffusion w/ dopant source present
② Drive-in: diffusion in an inert ambient, e.g., N_2 w/ no dopant gases present

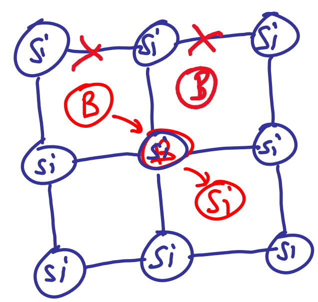
Ion Implantation

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

① Accelerate B+ ions into the Si-substrate



② B+ punches into the Si



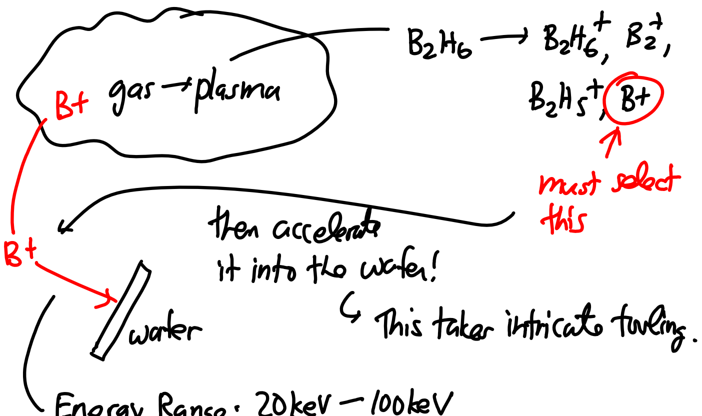
③ Raise T to move the B into the lattice → only when it's in the lattice is it active & can contribute to the doping level

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

Problem: COST!

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



Energy Range: 20keV – 100keV

Penetration Depth: fraction of a μm

⇒ larger ions don't go as far as smaller

(heavier ions penetrate shallower than smaller)

Dose: $10^{11} - 10^{15}\ cm^{-2}$

- Go through Diffusion slides in Module 4