EE C247B/ME C218: Introduction to MEMS Design
Lecture 7w: Process Modules

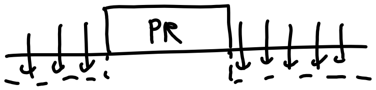
CTN 2/6/18

Lecture 7: Process Modules II

- Announcements:
- HW#2 has been online since Friday last week
- Lecture Modules 3 & 4 on Process Modules online
- Process Module Details lecture videos have been online: Lectures 7.x
- ------------------------------------
- Today:
- Senturia, Chpt. 3; Jaeger, Chpt. 2, 3, 6
  - Example MEMS fabrication processes
  - Photolithography
  - Etching
  - Oxidation
  - Film Deposition
  - Ion Implantation
  - Diffusion
- Reading: Senturia Chpt. 3, Jaeger Chpt. 11, Handout: "Surface Micromachining for Microelectromechanical Systems"
- Lecture Topics:
  - Polysilicon surface micromachining
  - …
- ------------------------------------
- Last Time:
- Going through process modules
- Now continue this …

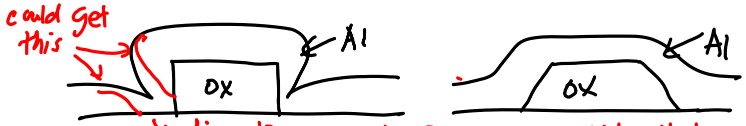
- Anistropic Etchant Examples:
  - Reactive ion etch
  - Ion milling

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



square profile & no undercut

- 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

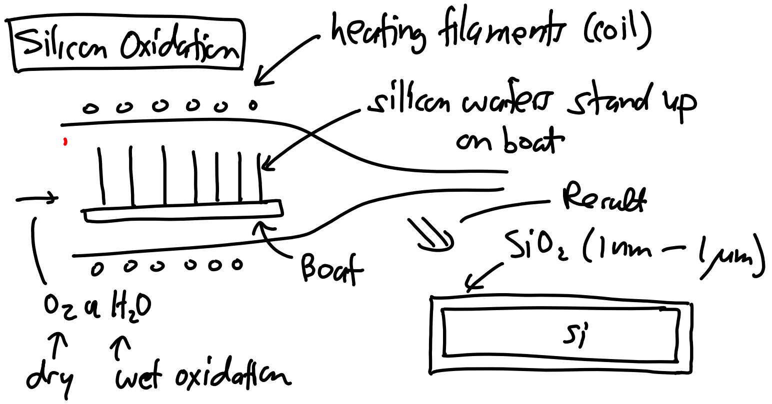


discontinuous metal film would spell trouble!

Too much topography → more difficult for subsequent films to conform

Sloped sidewalls allow better conformability

Silicon Oxidation

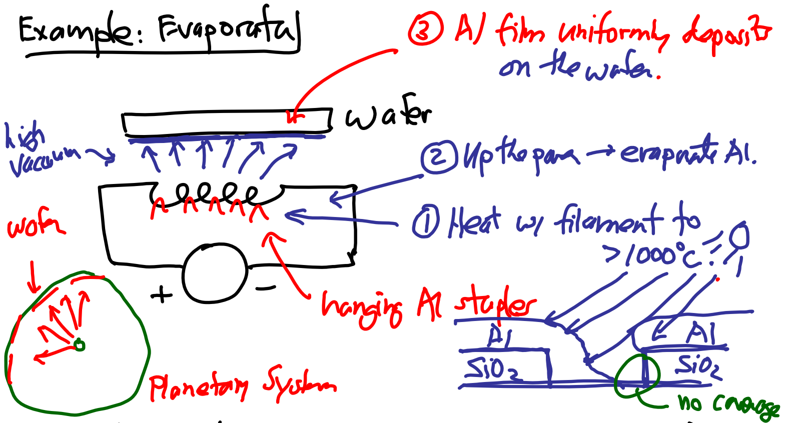


- **Remarks**:
  - Uniformity can be better than 2% across the wafer from lot to lot
  - Need to flow the O_2 fairly fast in order to minimize reactant losses from the first boat to the last one

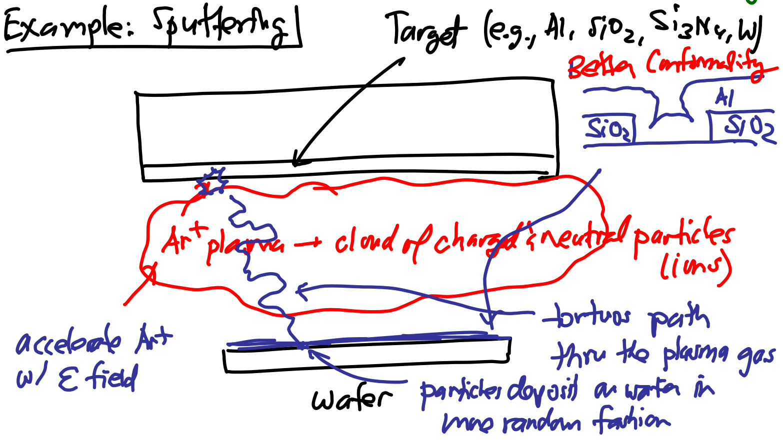
Thin-Film Deposition:

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

Example: Evaporation



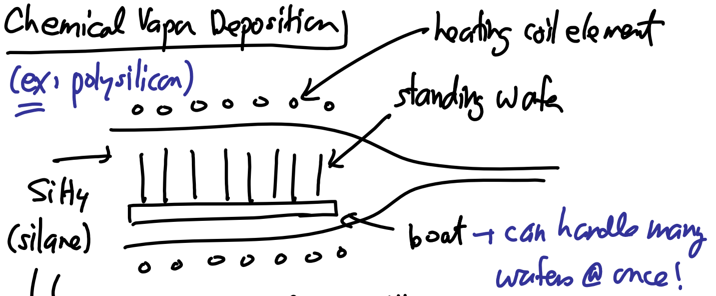
Example: Sputtering



- 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 Vapor Deposition

(ex: polysilicon)



585°C – 600°C for polysilicon

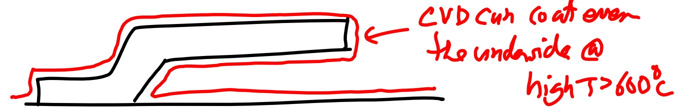
chemically decomposes to deposit poly Si

$$SiH_4 \xrightarrow[\text{25-150 Pa}]{} Si + 2H_2$$

600°C ← fairly high T

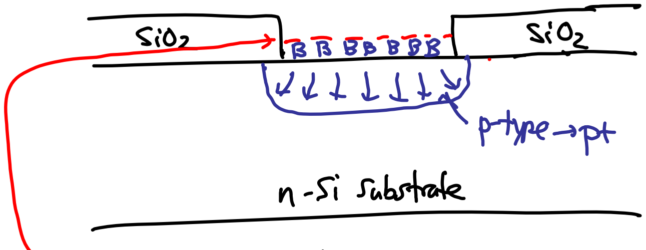
25-150 Pa ← low pressure (LPCVD)

- **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



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

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

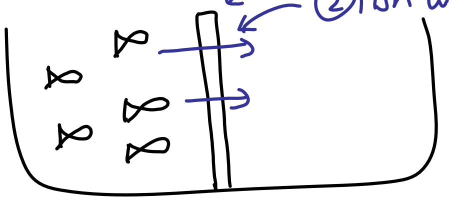


① Form borosilicate glass w/ high B concentration
② Boron diffuses in → this becomes p-type

⇒ diffusion requires:
① concentration gradient
② movement (velocity)

→ Example. Fish Tank

① When separator removed...
② Fish will go to the other side

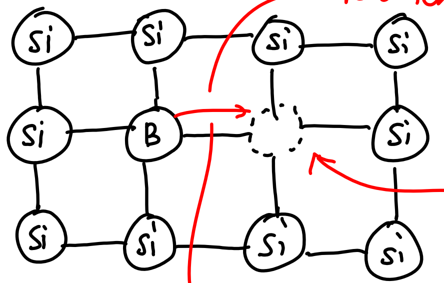


highly concentrated

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!

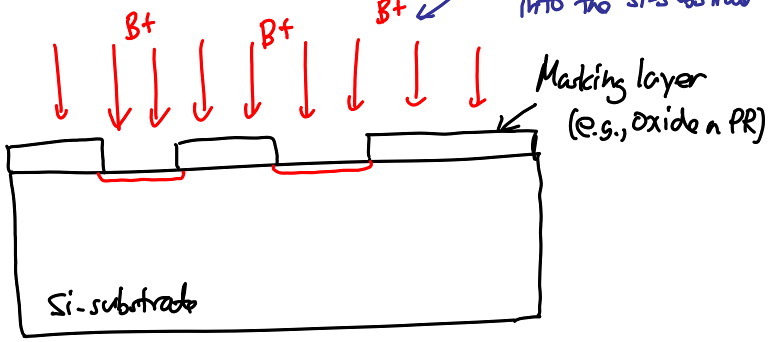
Definitions.

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

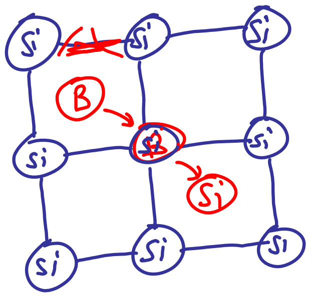
Ion Implantation

⇒ 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:

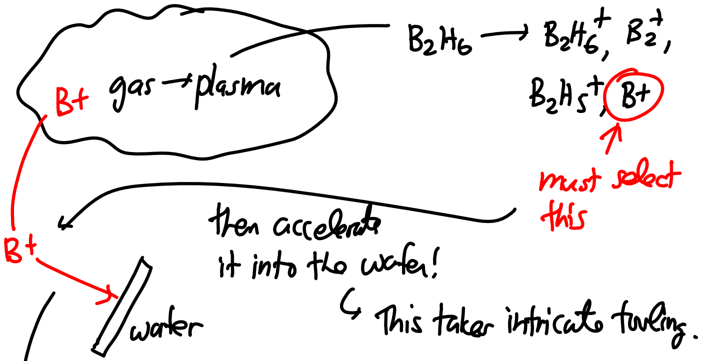
① accurate dose

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)



then accelerate it into the wafer!

↳ This takes intricate tooling.

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

- Now, start going through Module 5 on Surface Micromachining