Lecture 6: Process Modules

- Announcements:
- HW#1B due Wednesday next week at 8 a.m.
- Lecture Modules 3 & 4 on Process Modules online
- Lecture Module 5 on Surface Micromachining online
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- Today:
- Reading: Senturia, Chapter 1
- Lecture Topics:
  - Benefits of Miniaturization
  - Examples
    - GHz micromechanical resonators
    - Chip-scale atomic clock
    - Thermal Circuits
    - Micro gas chromatograph
- Senturia, Chpt. 3; Jaeger, Chpt. 2, 3, 6
  - Example MEMS fabrication processes
  - Photolithography
  - Etching
  - Oxidation
  - Film Deposition
  - Ion Implantation
  - Diffusion
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- Last Time:
- Finished thermal circuit modeling
- Now, spend a brief amount of time in Micro Gas Analyzers, then proceed with Process Modules

Process Module Overview:

- Lecture Topics:
  - Photolithography
  - Etching
  - Oxidation
  - Film Deposition
  - Ion Implantation
  - Diffusion
- As stated earlier, this is now assumed knowledge
- I will gloss over this material to review it a bit, but will not go over it in detail
- You can watch my lectures from EE245, Fall 2012, on the Webcast Berkeley site for more in depth coverage: Lectures 6-8
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Process Modules

⇒ there are actually only a few basic modules used for processing

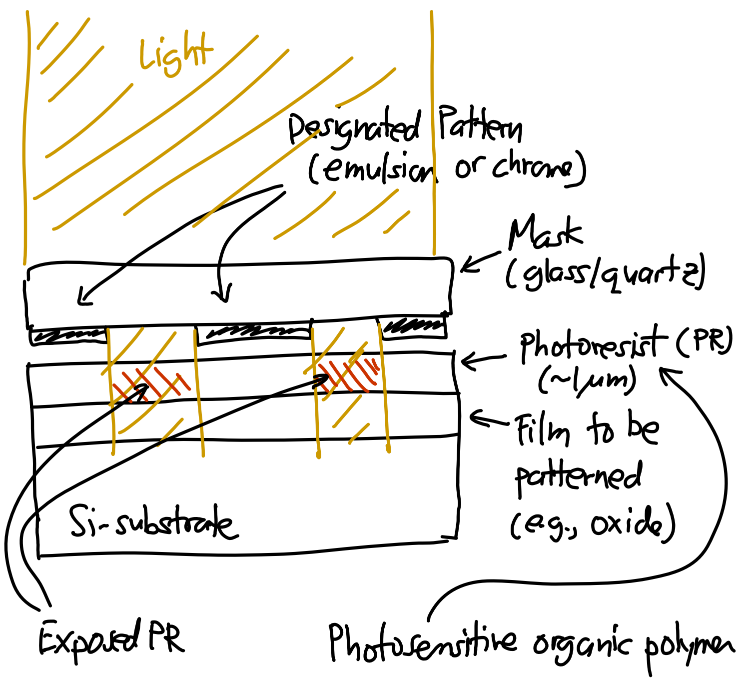
↓

Combination of these in the correct sequence yields an integrated circuit technology that provides transistors, MEMS, nanodevices, etc.

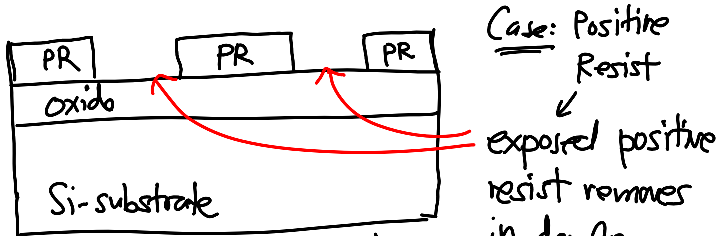
⇒ For each module, need to understand:

1. Physics and engineering of each module in detail.
2. Interactions between modules.
3. The effect of each module on the finished device.

Photolithography



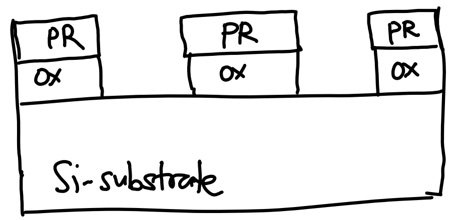
↓ Add developer (KOH)



⇒ Now, the PR is patterned
⇒ Ready for the next step: Etching

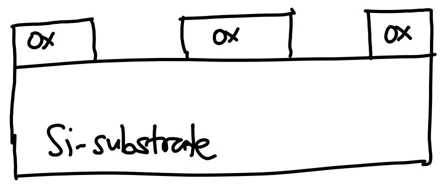
↓ *

↓ Etch oxide (using dry or wet etchant)



⇒ PR protects underlying oxide from etching

↓ Acetone or PRS 3000 (to remove the PR)



} oxide film now patterned

⇒ Above: collectively called a masking step

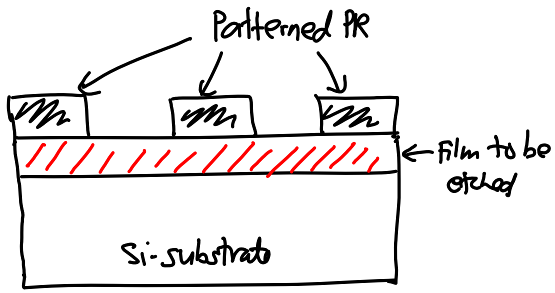
Usually gauge the cost & complexity of a given technology by the # masking steps!

Number of Masking Steps

- NMOS: 4–6 masks
- 1990 CMOS: 8–11 masks
- today's CMOS: >28 masks
- Bipolar: 11–13 masks
- BiCMOS: 20 masks

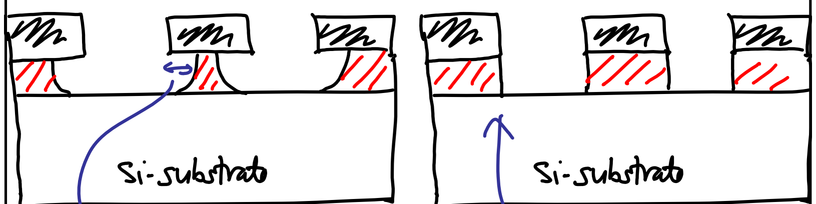
combination of bipolar & CMOS (mainly for RF/wireless apps.)

Etching



Etches the same rate in all directions } Isotropic Etch

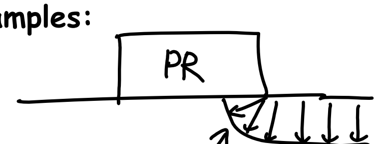
Anisotropic Etch { Etches in only one direction (e.g., straight down)



undercutting
→ not desirable when resolution is important
→ very desirable in MEMS, when a structure must be released

no undercutting
→ best resolution!

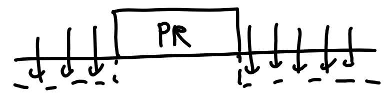
- Isotropic Etchant Examples:
  - Wet etchants
  - Dry plasma etch



get undercut & curved profile

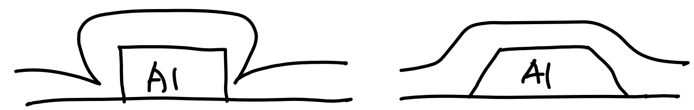
- Anistropic Etchant Examples:
  - Reactive ion etch
  - Ion milling

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



square profile & no undercut

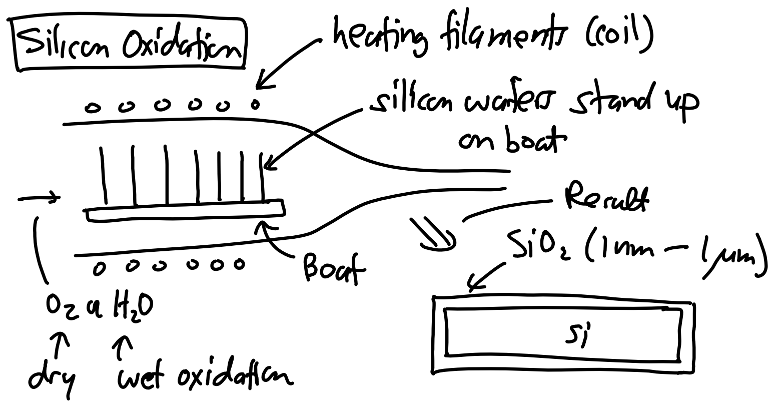
- **Remarks**:
  - Wet etching is fairly cheap
  - Dry etching requires a plasma, so requires some expensive equipment
  - Don't always want straight sidewalls



Too much topography → more difficult for subsequent films to conform

Sloped sidewalls allow better conformability

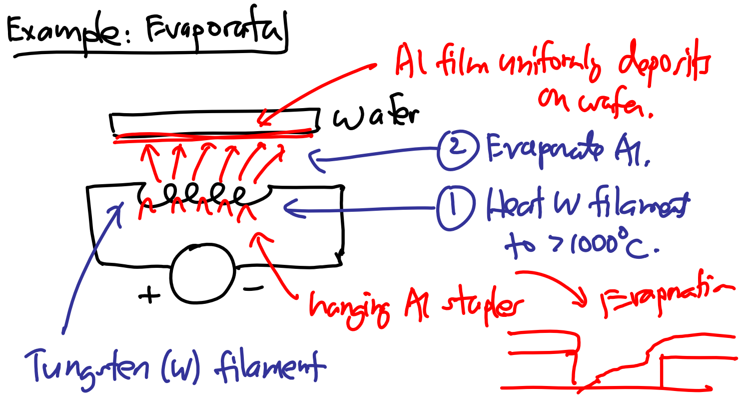
Silicon Oxidation

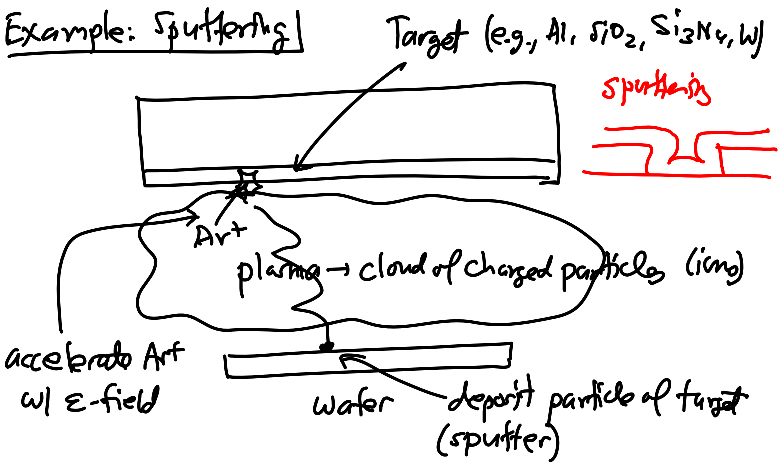


- **Remarks**:
  - Uniformity can be better than 2% across the wafer from lot to lot
  - Need to flow the O_2 fairly fast in order to minimize reactant losses from the first boat to the last one

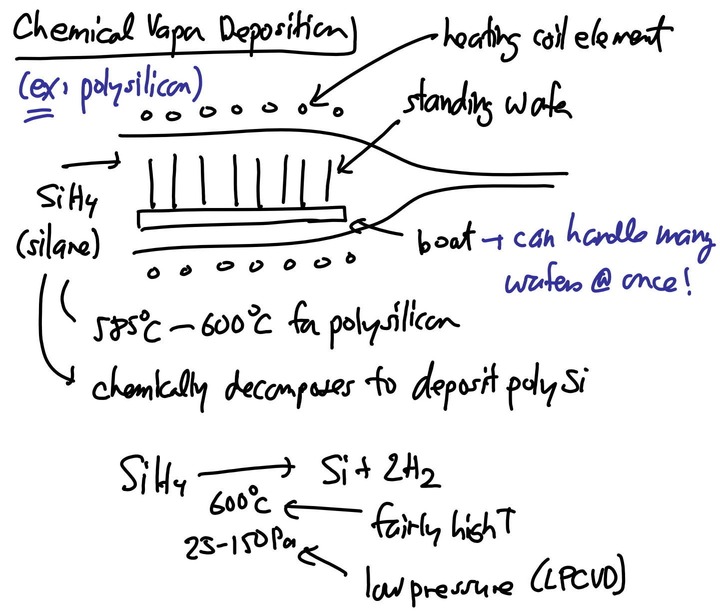
Thin-Film Deposition:

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

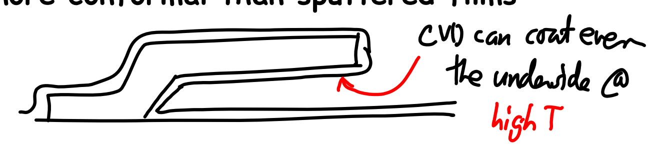




- Also, have chemical vapor deposition (CVD)
  - Chemical reaction involved in deposition of a given thin film
  - High temperature, but not nearly as high as often required for thermal growth

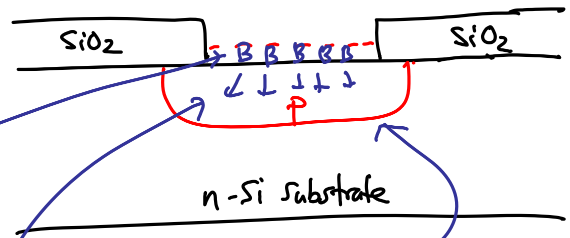


- **Remarks**:
  - Lot's of materials can be deposited in a similar manner: polysilicon, SiO_2, Si_3N_4, tungsten
  - Compared to sputtering, CVD is less expensive since one can coat many wafers at once; sputtering generally does it one at a time
  - For higher temperature, CVD films are much more conformal than sputtered films



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

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

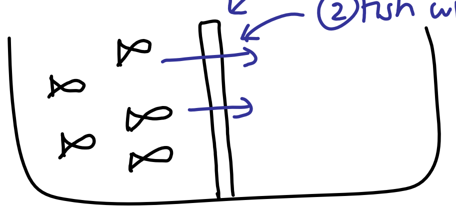


① Form borosilicate glass w/ high B concentration
② Boron diffuses in → this becomes p-type

⇒ 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!