Lecture 4: Process Module Overview

- Announcements:
  - Lab sections now settled
  - Thursday section moves to 8-11 a.m.
  - HW#1 distributed
  - Pdf copy of the Tuesday lecture online
  - Next Week: Wei-Chang lectures all week, both Tuesday and Thursday
  - My Thursday office hour: back to 10:30-12 noon
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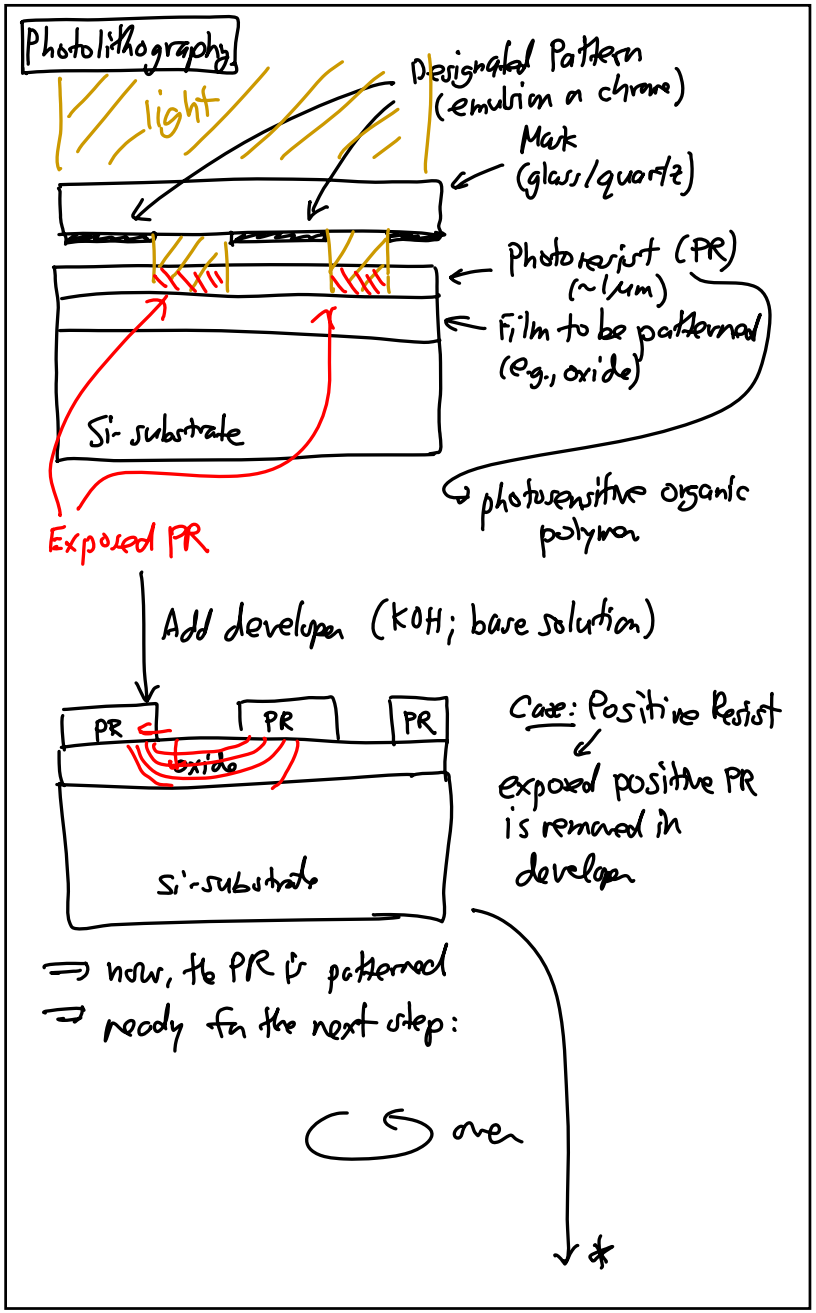
- Lecture Topics:
  - Photolithography
  - Etching
  - Oxidation
  - Film Deposition
  - Ion Implantation
  - Diffusion

Process Modules of interest

- ---

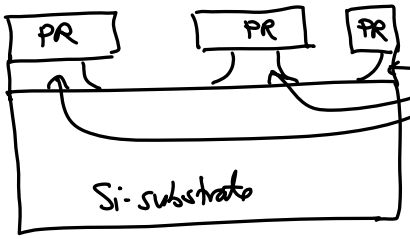
→ combination of these in a correct sequence yields an integrated circuit technology that provides transistors, MEMS, nanodevices, ...

For each module need to understand
1. physics & engineering in detail (equations).
2. Interactions between modules.
3. The effect of each module on the finished device.



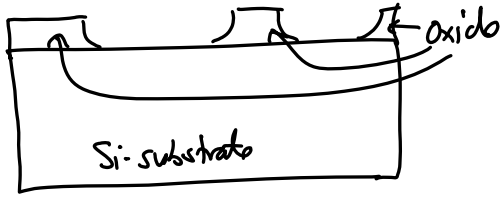
Etching

* Etch Oxide (using dry or wet etchant)
↳ hydrofluoric acid (HF)



→ could do a better job w/ dry etching

Remove PR: Acetone or PRS3000 (or dry: O_2 plasma)

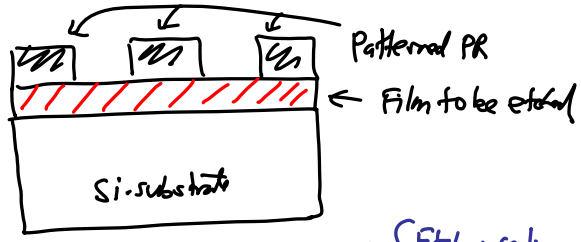


⇒ Above: collectively called a masking step

Number Masking Steps

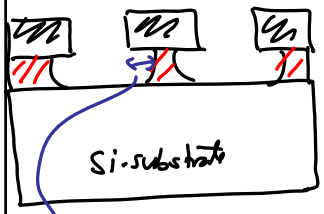
NMOS (1980's): 4-6 masks
1990 CMOS: 8-11 masks
today's CMOS: > 28 masks
Bipolar: 11-13 masks
BiCMOS: 20 masks
EE 143: 4-5 masks

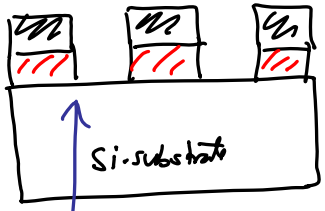
Etching



Etches the same rate in all directions } Isotropic Etch

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



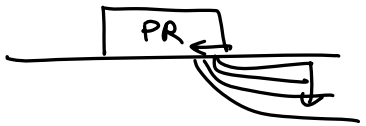


Undercutting
↓
not desirable when resolution is important
very desirable in MEMS, when a structure must be released

no undercutting (ideally)
↓
Best Resolution!

Examples of Isotropic Etchants:

⇒ wet etchant (not all of them, e.g., (111) Si)
⇒ dry plasma etch



Anisotropic Etchants

⇒ reactive ion etch (RIE) → use ions under E-fields to give the etch directivity!

⇒ ion milling

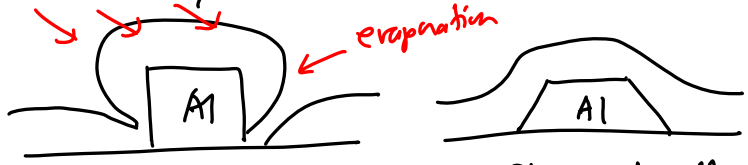
etchant w/ directivity

Remarks:

① Wet etching is fairly cheap.

② Dry etching requires a plasma → expensive tooling.

③ Don't always want straight sidewalls:

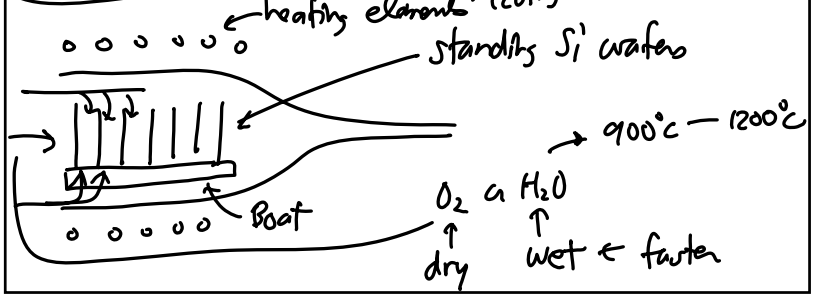


Too much topography → more difficult for subsequent films to conform

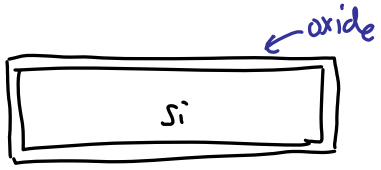
Sloped sidewalls allow better conformability

Silicon Oxidation

⇒ thermal growth of SiO_2



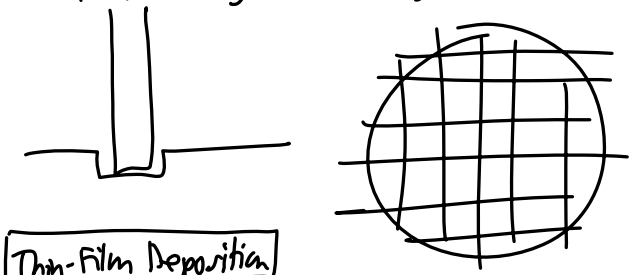
Result:



Remarks:

① Uniformity can be better than 2% across the wafer.

② Need to flow the O_2 or H_2O sufficiently fast to insure good uniformity from wafer to wafer.

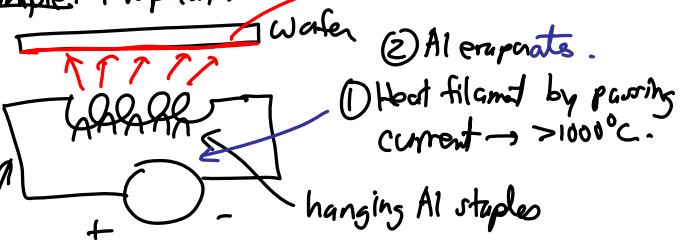


Thin-Film Deposition

⇒ deposition, not thermal growth → much lower temp. than thermal growth

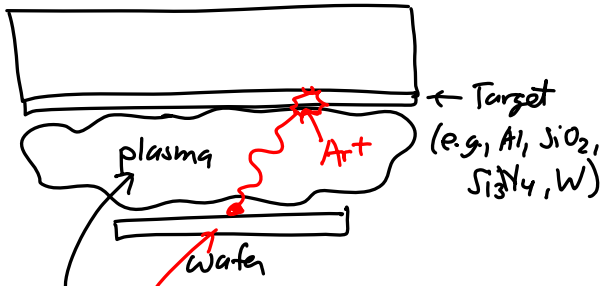
⇒ For Al, W, SiO_2, Si_3N_4, polySi

Example: Evaporator



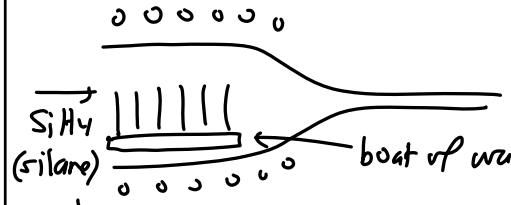
Tungsten (W) filament → very high melting temp.

Example: Sputtering



deposit target particle on the wafer → sputter

Example: Chemical Vapor Deposition (CVD)
(ex: poly-Si)



575°C – 650°C for poly-Si

$SiH_4 \rightarrow Si + 2H_2$

600°C ← fairly high T (but not nearly as hot as thermal grade)

25-150 Pa (~300 mTorr) ↑ low pressure (LPCVD)

→ the higher the T → more conformal film

Conformability