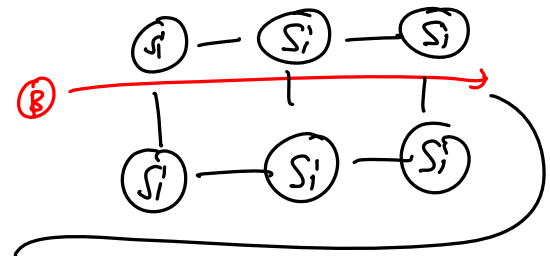
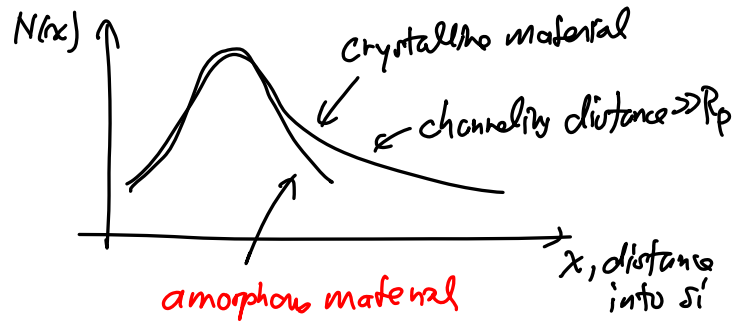
Lecture 17: Diffusion I

- Announcements:
- HW#7 due tomorrow (Friday) at 8 a.m.
- Module 5 on Ion Implantation online
- Module 6 on Diffusion online
- Midterm Exam: coming Thursday, Oct. 30
  - It'll be during lecture
  - Review Session: Tu 6:30-8:30 p.m., 293 Cory
  - TA's will be running the review session
  - Passed out old midterm exam
  - Went through midterm info sheet
- ---
- Lecture Topics:
  - Diffusion
    - Basic Process for Selective Doping
    - Diffusion Modeling
    - Predeposition Modeling
    - Drive-in Modeling
    - Successive Diffusions
    - Diffusion Coefficient
    - Junction Depth
    - Sheet Resistance
    - Irvin's Curves
- ---
- Last Time: Channeling

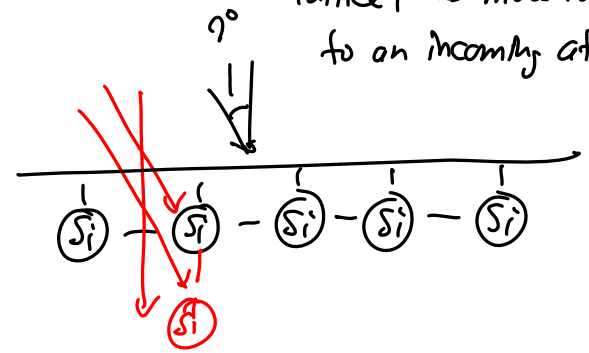
⇒ LSS theory assumes amorphous material
↳ true for SiO_2, deposited SiO_2, & metals
↳ not true for Si



for this → get channeling



One Solution: use 7° off-axis implant
↳ lattice looks more random to an incoming atom!



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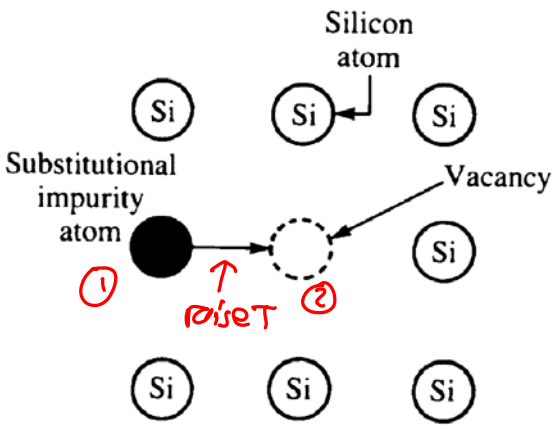
Diffusion

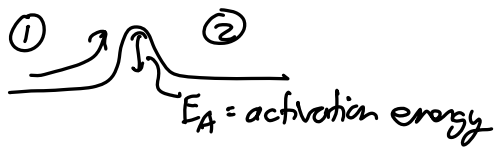
⇒ movement of dopants within the Si at high temperatures

Three Mechanisms: (in Si)

① Substitutional Diffusion:



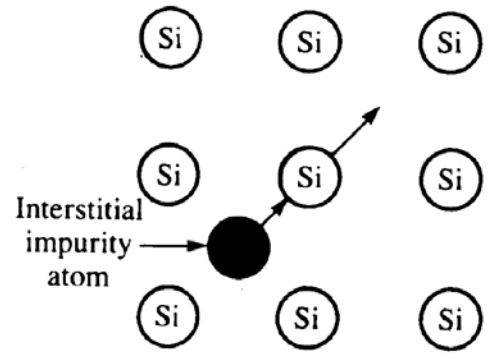
(a)



⇒ impurity atom moves along vacancies in the lattice when T raised

⇒ it substitutes for a Si-atom in the lattice
↳ it's activated

② Interstitialcy Diffusion:

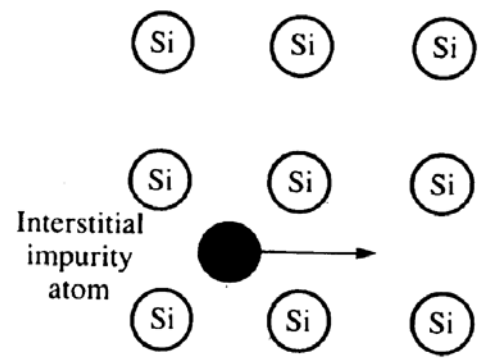


(b)

⇒ impurity atom replaces a Si atom in the lattice

⇒ Si displaced to an interstitial site

③ Interstitial Diffusion:



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⇒ impurity atoms jump from one interstitial site to another

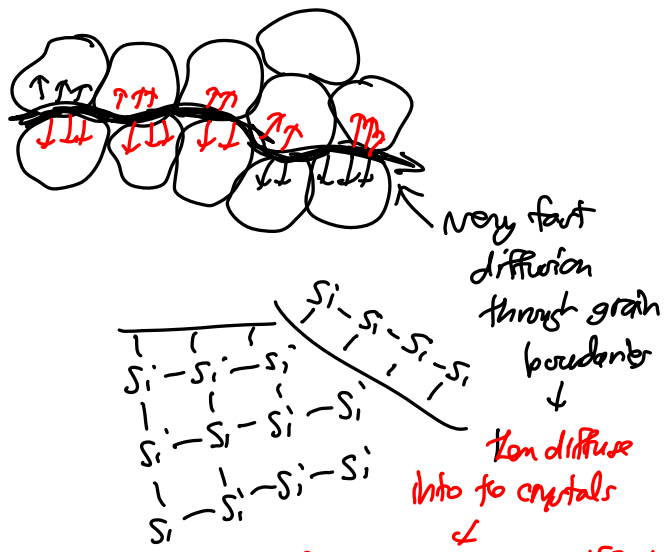
⇒ do not replace Si atoms in the lattice

∴ get rapid diffusion

↳ hard control

↳ impurity not in the lattice during transport, but often eventually ends up in the lattice

Diffusion in poly Si



very fast diffusion through grain boundaries

↓

can diffuse into the crystals

↓

Result: 10x faster diffusion (10x larger D)

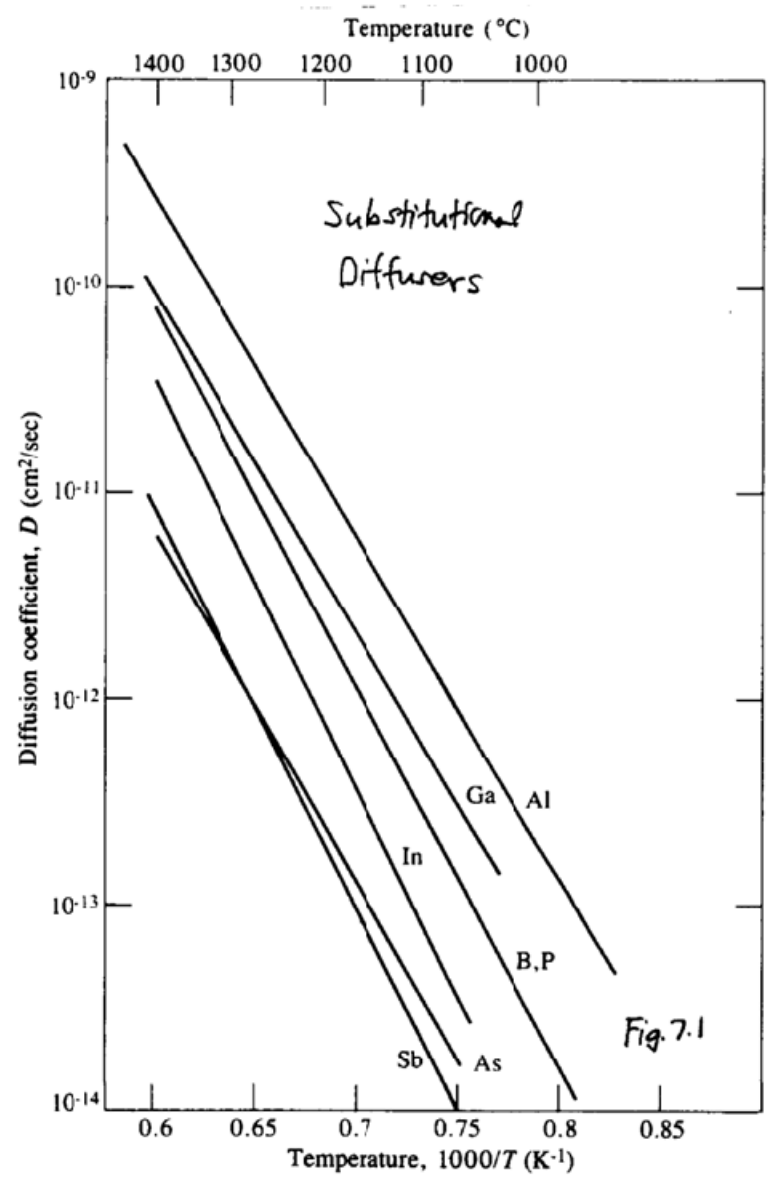


Fig. 7.1

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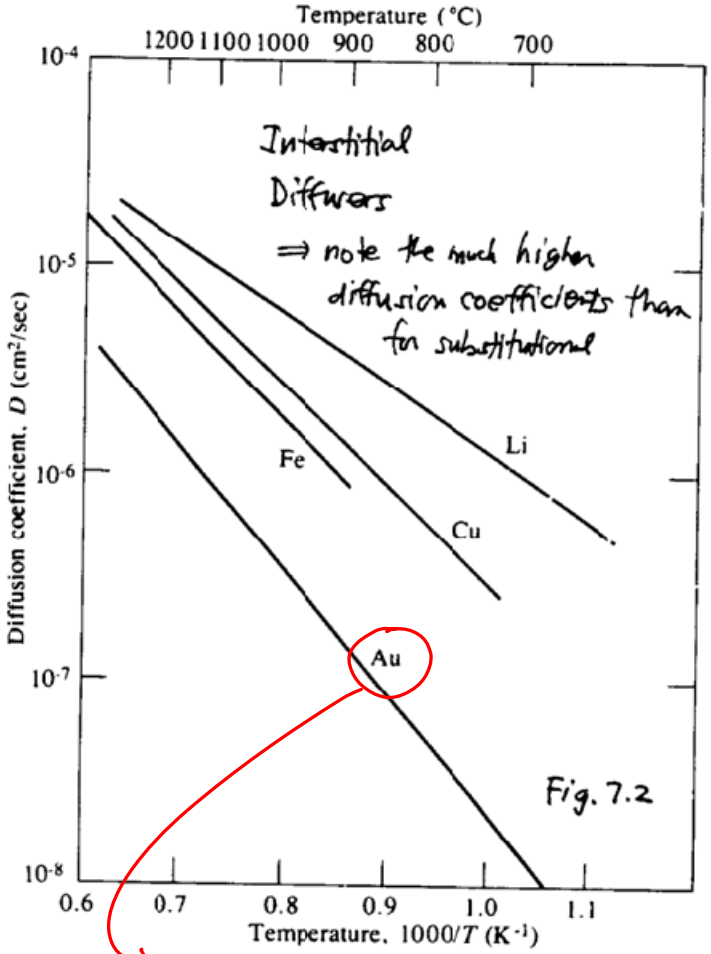
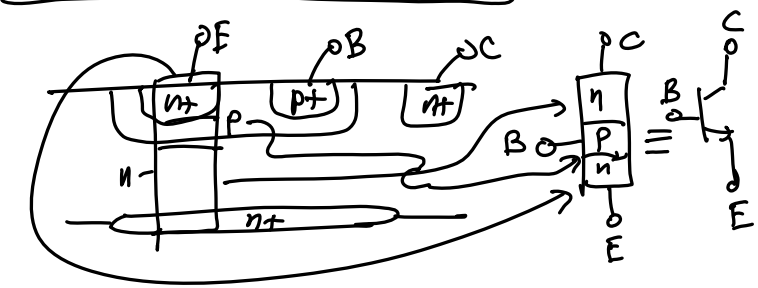


Interstitial Diffusers
⇒ note the much higher diffusion coefficients than for substitutional

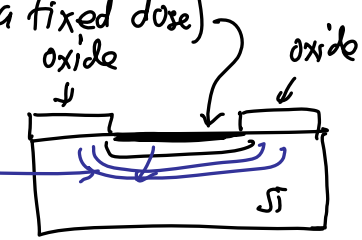
Fig. 7.2

Au & other metals problematic for semiconductor devices
the fact that they diffuse fast just means more trouble!

Basic Process for Selective Doping



① Introduce the dopants (a fixed dose)
(i) ion implantation
(ii) predeposition



② Drive-in dopant to the desired depth
↳ high T > 900°C in N_2 or N_2/O_2

Predeposition

⇒ furnace-tube system using solid, liquid, or gaseous dopant sources
⇒ used to introduce a <u>controlled</u> amount of dopants
⇒ for pre-deposition, control not as good as I/I
⇒ Dose (Q) range: $10^{13} - 10^{16} \pm 20\%$ (pre-dep)
(for I/I: $10^{11} - 10^{16} \pm 1\%$)

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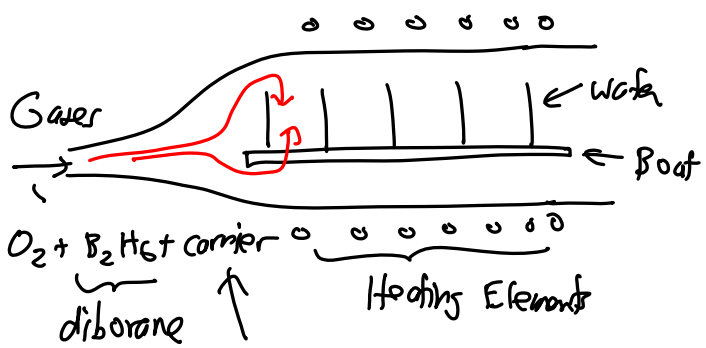
Example: Boron predeposition

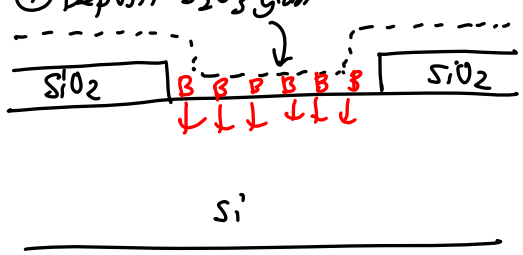


Reactions:

$$B_2H_6 + 3O_2 \rightarrow 3H_2O + B_2O_3$$

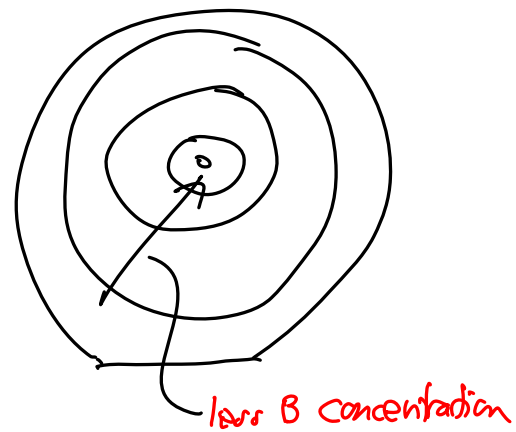
$$Si + O_2 \rightarrow SiO_2$$

① Deposit B_2O_3 glass

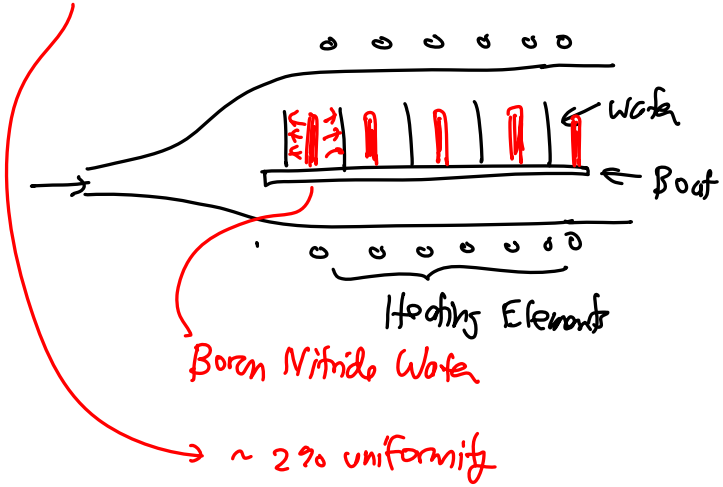


② B diffuses from $B_2O_3 \rightarrow Si$

⇒ difficult control dose:



For better uniformity, use Solid Sources:



→ ~ 2% uniformity

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