EE 143: Microfabrication Technology
Lecture 16c: Ion Implantation

CTN 3/11/10

Lecture 16: Ion Implantation

- **Announcements**:
- Need volunteers for Cal Day (April 17):
  - Alumni & prospective students visit Cal
  - If interested, sign up with your lab TA
- HW#6:
  - Add problem 5.2 and 5.4 from Jaegar
  - HW#6 due next Tuesday, 3/16/10, 7 p.m.
  - The unlabeled box in problem 1 is polySi
- Midterm Exam: coming Thursday, March 18
  - It'll be during lecture
  - Review Session Time: Tu 6-8 p.m., in 293 Cory
  - TA's will be running the review session
  - Passed out information sheet on the exam
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- **Lecture Topics**:
  - Ion Implantation
    - Gaussian Distribution
    - Range, Straggle, & Lateral Straggle
    - Masking
    - Junction Depth
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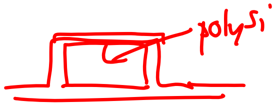
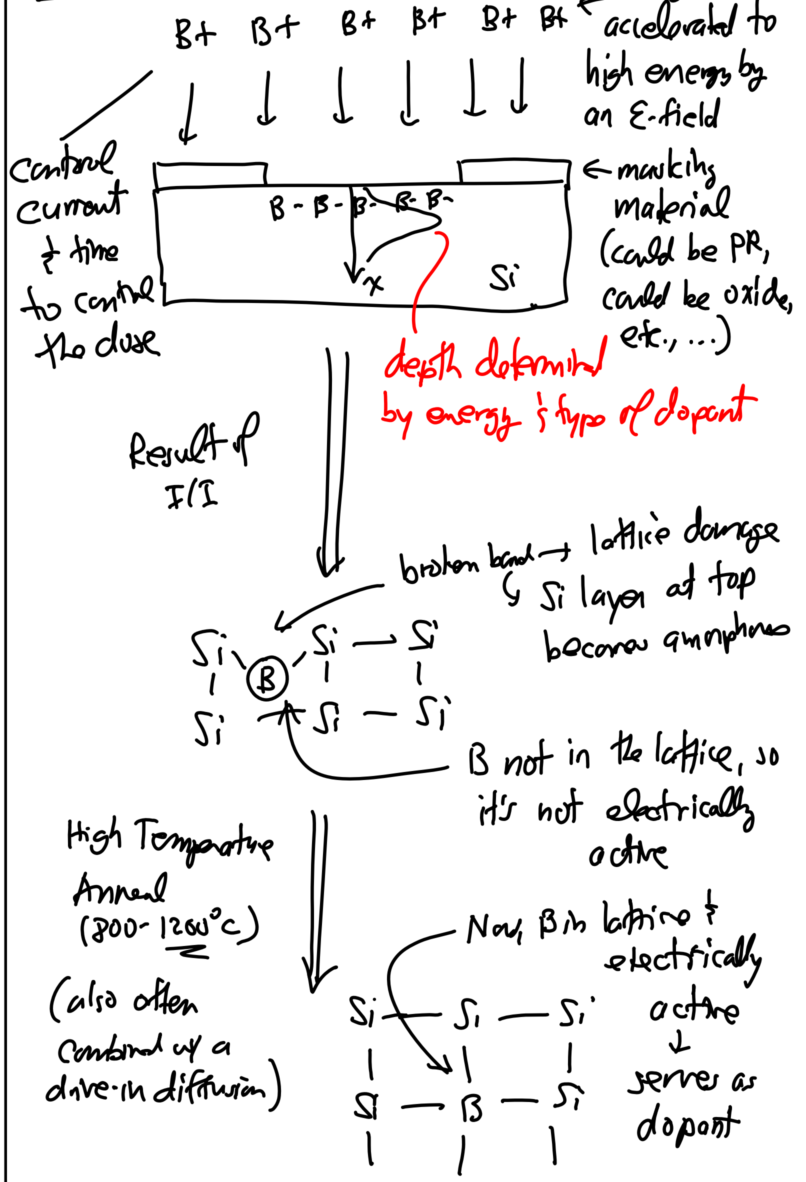
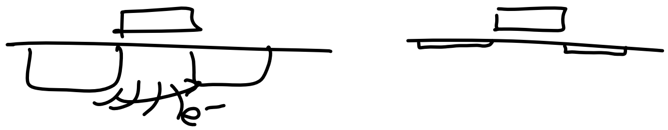


Ion Implantation

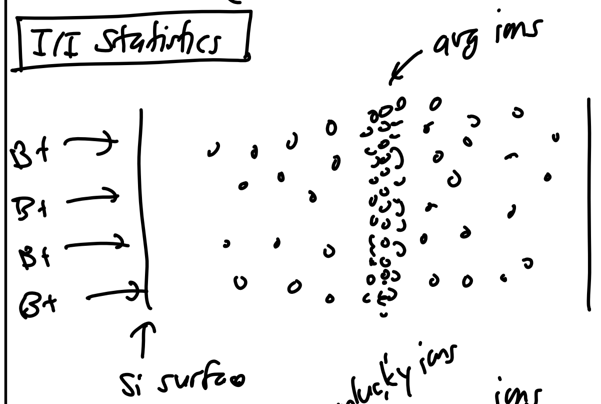
⇒ method by which dopants can be introduced into Si (actually into anything) to form, e.g., pn-junctions, S/D junctions, & to set threshold voltages

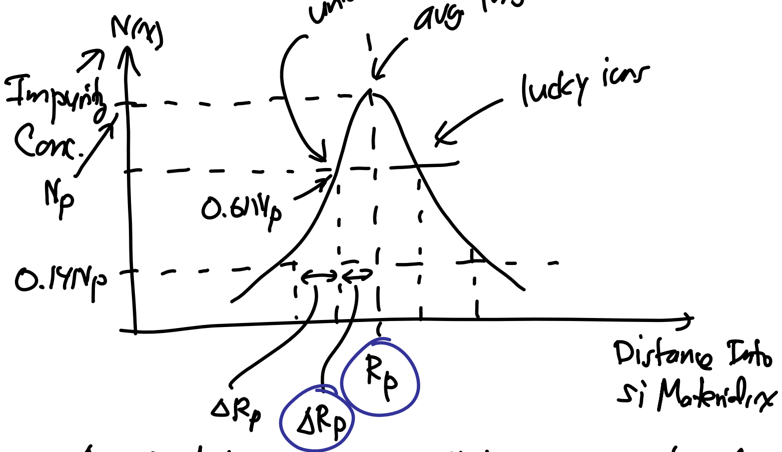
The Basic Process:





I/I Statistics





$R_p \overset{\Delta}{=}$ projected range = avg. distance an ion travels before stopping

$\Delta R_p \overset{\Delta}{=}$ straggle = std. deviation characterizing the spread of the distribution

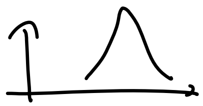
Mathematically:

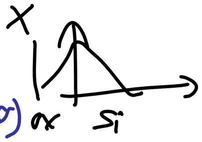
$$N(x) = N_p \exp\left[-\frac{(x-R_p)^2}{2(\Delta R_p)^2}\right]$$

Area under the impurity distribution curve = Implanted Dose = $Q = \int_0^\infty N(x)dx$ [ions/cm^2]

Case: For an implant completely contained in the Si:

$Q = \sqrt{2\pi}\, N_p \Delta R_p$ →





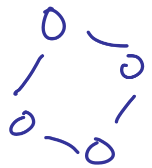
Lindhard, Scharff, and Schiott (LSS)

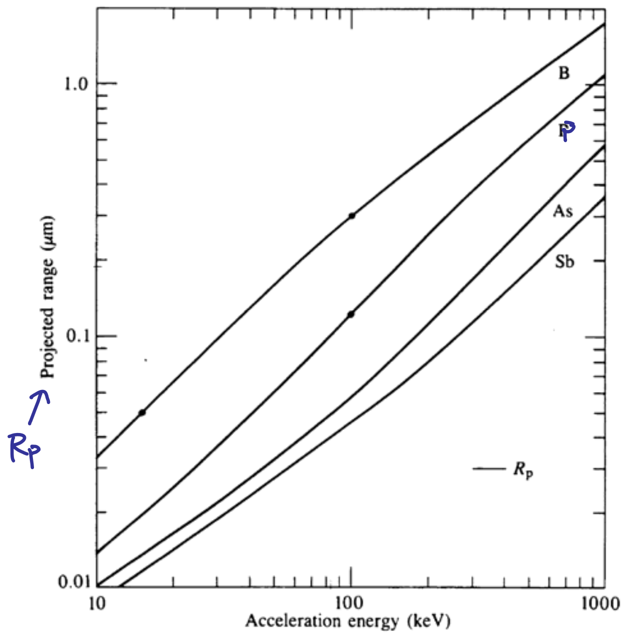
Theory: assumption: implant into an amorphous material

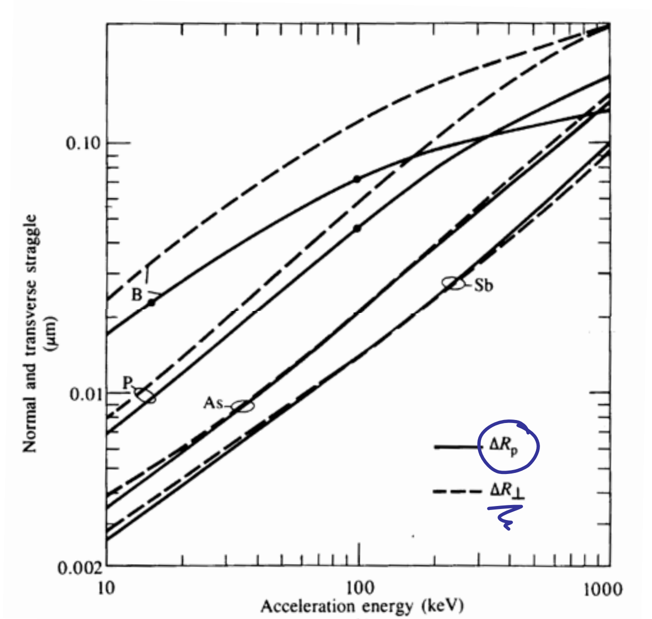
↳ atoms in target material randomly positioned

↓ works well for SiO_2

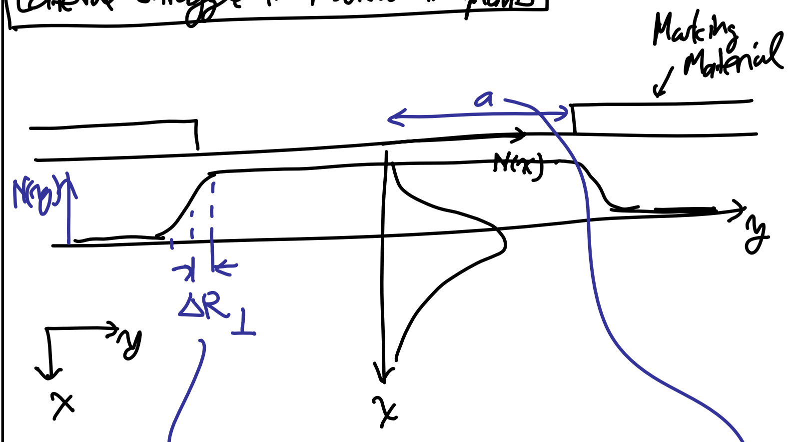
↳ also works for Si







Lateral Straggle in Masked Implants



lateral straggle std. deviation
= $\Delta R_\perp$ → (transverse straggle)

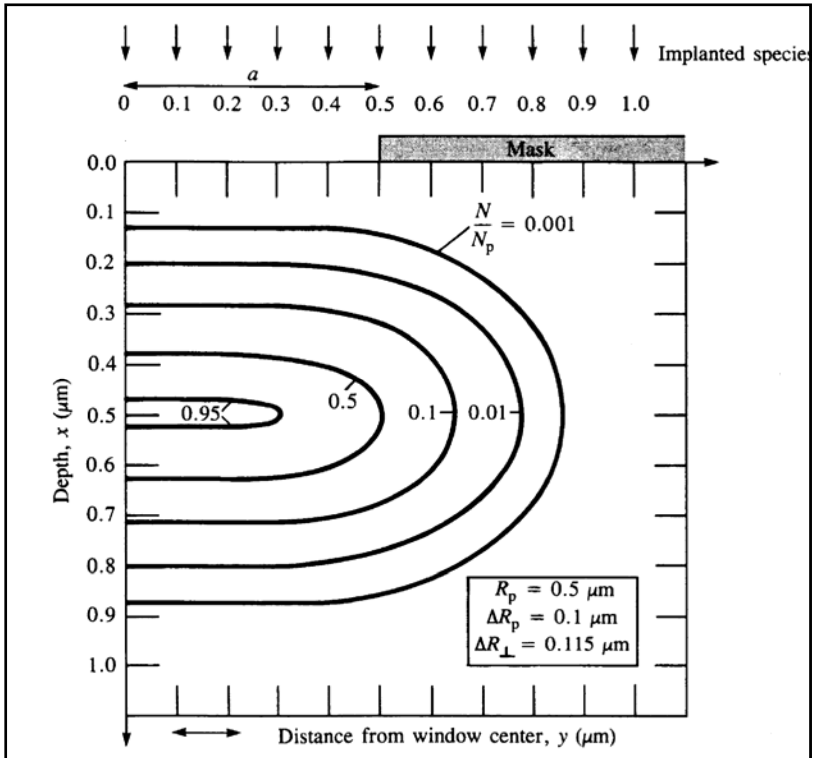
→ can model the whole distribution:

$$N(x,y) = N(x)F(y)$$

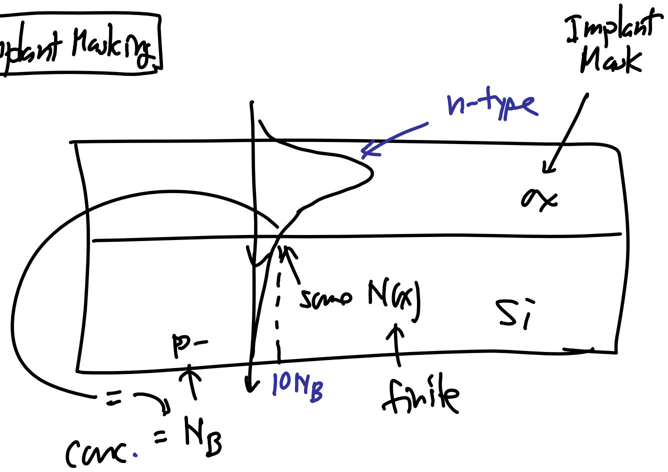
$$F(y) = \frac{1}{2}\left[\operatorname{erfc}\left\{\frac{(y-a)}{\sqrt{2}\,\Delta R_\perp}\right\} - \operatorname{erfc}\left\{\frac{(y+a)}{\sqrt{2}\,\Delta R_\perp}\right\}\right]$$

Complementary error function:

$$\operatorname{erfc}(x) = \frac{2}{\sqrt{\pi}}\int_x^\infty e^{-t^2}\,dt$$

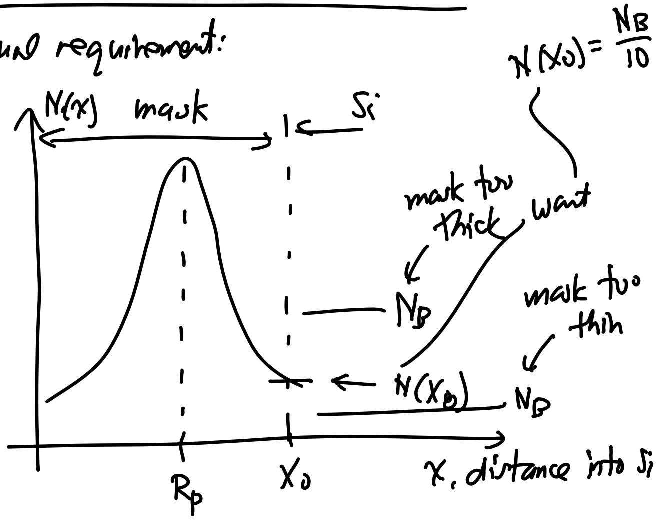


Implant Masking



How thick must the masking material be?

⇒ usual requirement:



Want: $N(x_0) < \frac{N_B}{10}$

$$N_p \exp\left[-\frac{(x_0 - R_p)^2}{2\Delta R_p^2}\right] < \frac{N_B}{10}$$

Solve for x_0:

$$x_0 = R_p + \Delta R_p \sqrt{2 \ln\left(\frac{10 N_p}{N_B}\right)}$$

$$= R_p + m \Delta R_p$$

projected range + some multiple × straggle

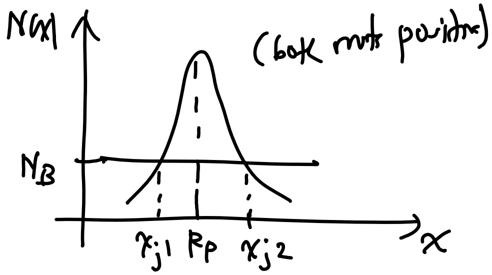
Junction Depth

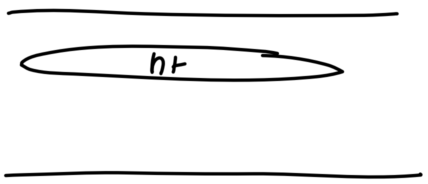
⇒ defined as the depth @ which the implanted dose = N_B (the background conc.)

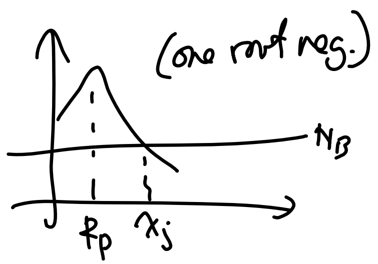
$$N_p \exp\left[\frac{-(x_j - R_p)^2}{2\Delta R_p^2}\right] = N_B$$

$$\Rightarrow \boxed{x_j = R_p \pm \Delta R_p \sqrt{2\ln\left(\frac{N_p}{N_B}\right)}}$$

both roots may be meaningful for deep implantations:

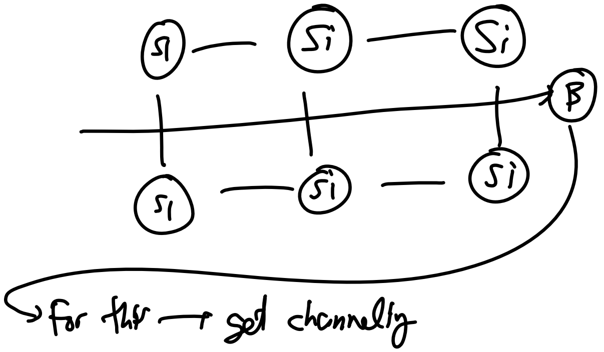




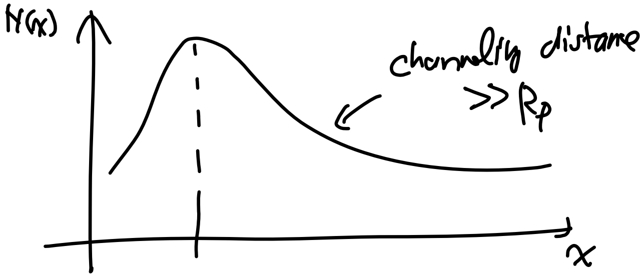


Channeling

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



for this → get channeling



channeling distance $>> R_p$

One solution: use 7° off-axis implant

↳ lattice looks more random to incoming atom!