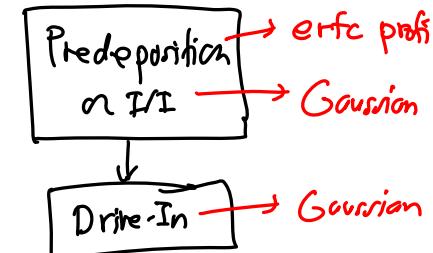


Lecture 19w: Diffusion IIILecture 19: Diffusion II

- Announcements:
 - HW#8 online and due next Wednesday, 8 a.m.
 - Graded exams coming back at the end of class
 - Lab 1 Report will be due Tuesday, Dec. 2, at 8 a.m. in the 143 homework box
 - Instructions for the report already online via the EE143 Lab link
 - One lab report for each group
 - You can (and should) start on it now!
- Lecture Topics:
 - 8 → Wednesday, Nov. 26, 8 a.m.
 - 15 → Friday, Dec. 2, 8 a.m.
 - 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:

over

Two-Step Diffusion

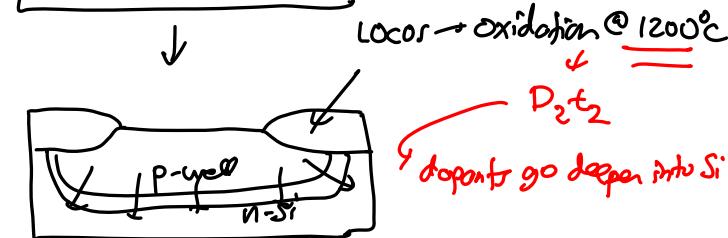
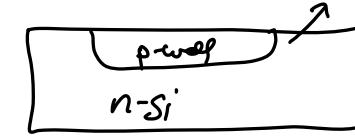
→ Governed by the relative (D_t) products.

$(D_t)_{\text{predep}} \gg (D_t)_{\text{drive-in}} \Rightarrow$ impurity profile is erfc

$(D_t)_{\text{drive-in}} \gg (D_t)_{\text{predep}} \Rightarrow$ Gaussian
usually the case

Successive Diffusions

diffusion constant @ Temp D_{t_1}



Lecture 19w: Diffusion III

For actual processes \rightarrow junction formation is only one of many high temp. steps!

(1) Selective Doping:

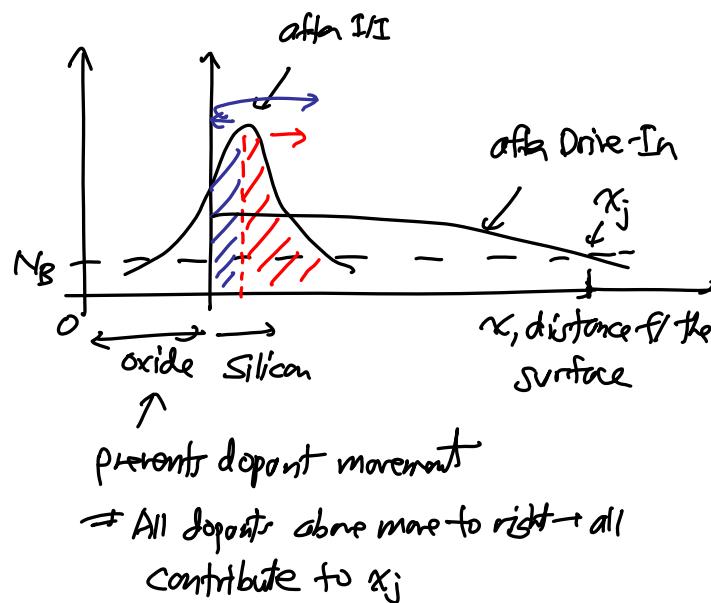
$$(a) \text{ implant} \rightarrow \text{effective } (Dt)_{\text{eff}} = \frac{(\Delta R_p)^2}{2}$$

$$(b) \text{ drive-in/activation} \quad (\text{it's Gaussian})$$

$$D_2 t_2$$

(2) Other high-temp. steps: $D_3 t_3, D_4 t_4, D_5 t_5, \dots$

$$(Dt)_{\text{tot}} = \sum_i D_i t_i$$

Revisit the Gaussian distribution

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

\Rightarrow in statistics courses, usually see this in the form:

$$f_x(x) = \frac{1}{\sigma \sqrt{2\pi}} \exp \left[-\frac{1}{2} \left(\frac{x-\mu}{\sigma} \right)^2 \right] \quad -\infty < x < \infty$$

This form is normalized std. dev.

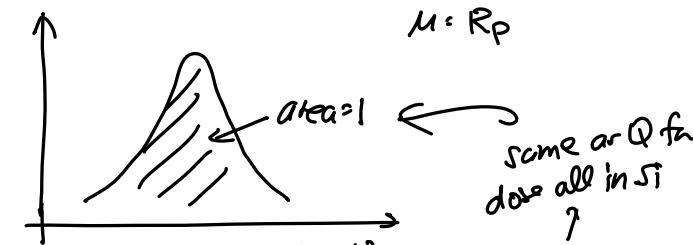
so that the area under the whole Gaussian distribution curve = 1

For doping, the area under the curve is the dose Q .

Thus, in this equation: $I \rightarrow Q$

$$\sigma \rightarrow \Delta R_p$$

$$\mu \rightarrow R_p$$



Why is $(Dt)_{\text{eff}, \text{II/II}} = \frac{(\Delta R_p)^2}{2}$?

For II/II completely contained in the Si:

$$Q = \sqrt{2\pi} N_p \Delta R_p \rightarrow N_p = \frac{Q}{\sqrt{2\pi} \Delta R_p} = \frac{Q}{\sqrt{2\pi} \Delta R_p}$$

Lecture 19w: Diffusion III

Rearrange to the form of the limited-source diffusion Gaussian, i.e., the half-Gaussian:

$$N_p = \frac{Q}{\Delta R_p \sqrt{2\pi}} = \frac{D_I}{\Delta R_p \sqrt{2\pi}} = \frac{\frac{D_I}{2}}{\frac{\Delta R_p}{2} \sqrt{2\pi}} =$$

$$= \frac{\frac{D_I}{2}}{\sqrt{2\pi} \left(\frac{(\Delta R_p)^2}{4} \right)} = \frac{D_I/2}{\sqrt{\pi} (\Delta t_{\text{eff}, I/I})}$$

$$\therefore (\Delta t)_{\text{eff, If}} = \frac{(\Delta R_p)^2}{2}$$

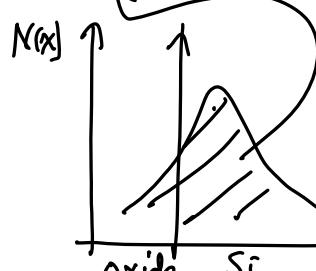
To summarize:

① For II, we use a two-sided Gaussian

expression:

$$N(x) = \frac{Q}{\sqrt{2\pi} \Delta R_p} \exp \left[-\frac{1}{2} \frac{(x - R_p)^2}{(\Delta R_p)^2} \right]$$

where Q = implanted dose, D_I ($Q = D_I$)



whether or not the implantation is all in the Si

② For limited-source diffusion, use a one-sided Gaussian expression:

$$N(x) = \frac{Q}{\sqrt{\pi} (\Delta t)} \exp \left[-\frac{1}{2} \frac{x}{\sqrt{\Delta t}} \right]^2$$

where if

$x_{s0} \triangleq$ initial peak dopant depth (before diffusion)

$x_s \triangleq$ final dopant depth (after drive-in)

↳ this often \approx junction depth, x_j

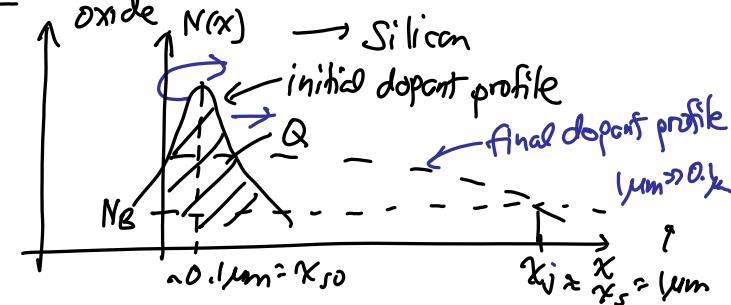
then

(i) Case: $x_{s0} \ll x_s$ → there's a diffusion barrier above the Si surface (e.g., oxide)

Q = total dose in the silicon

(not including dopants in the masking material)

Ex.



(ii) Case: $x_{r0} \geq x_s$ w/ diffusion barrier above Si surface

then $Q = \frac{1}{2} D_I$ (where D_I = total implanted dose)

and

$$N(x) = \frac{Q}{\sqrt{\pi(Dt)}} \exp \left[-\frac{1}{2} \frac{(x-x_{r0})}{\sqrt{Dt}} \right]^2$$

should be used.