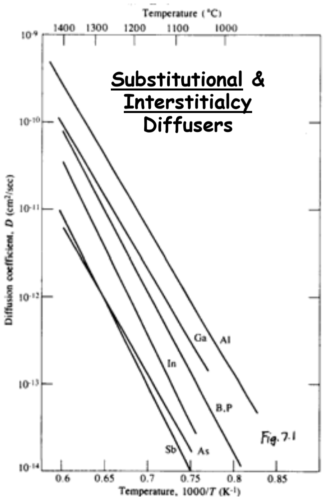
The Diffusion Coefficient

$$D = D_o \exp\left(-\frac{E_A}{kT}\right)$$ (as usual, an Arrhenius relationship)

Table 4.1 Typical Diffusion Coefficient Values for a Number of Impurities.

Element	D_o(cm^2/sec)	E_A(eV)
B	10.5	3.69
Al	8.00	3.47
Ga	3.60	3.51
In	16.5	3.90
P	10.5	3.69
As	0.32	3.56
Sb	5.60	3.95

Diffusion Coefficient Graphs



Substitutional & **Interstitialcy** Diffusers

Fig. 7.1

Interstitial Diffusers

↳ Note the much higher diffusion coeffs. than for substitutional

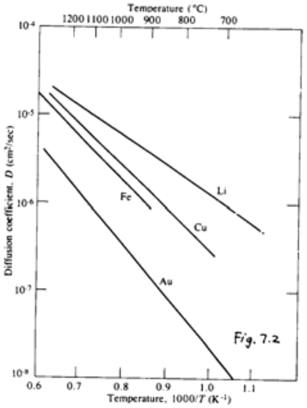
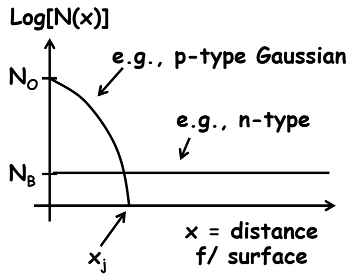
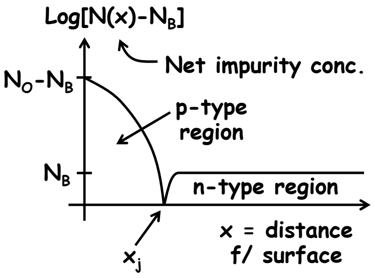


Fig. 7.2

Metallurgical Junction Depth, x_j

x_j = point at which diffused impurity profile intersects the background concentration, N_B





Expressions for x_j

- Assuming a Gaussian dopant profile: (the most common case)

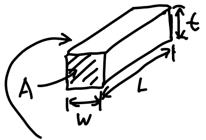
$$N(x_j,t) = N_o \exp\left[-\left(\frac{x_j}{2\sqrt{Dt}}\right)^2\right] = N_B \rightarrow x_j = 2\sqrt{Dt\ln\left(\frac{N_o}{N_B}\right)}$$

- For a complementary error function profile:

$$N(x_j,t) = N_o \operatorname{erfc}\left(\frac{x_j}{2\sqrt{Dt}}\right) = N_B \rightarrow x_j = 2\sqrt{Dt}\operatorname{erfc}^{-1}\left(\frac{N_B}{N_o}\right)$$

Sheet Resistance

- Sheet resistance provides a simple way to determine the resistance of a given conductive trace by merely counting the number of effective squares
- Definition:



$$R=\frac{\rho L}{A}=\left(\frac{\rho}{t}\right)\frac{L}{W}=R_s\left(\frac{L}{W}\right)$$

[A=tW]

sheet resistance

unit squares of material in the resistor

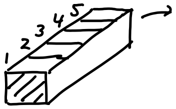
ohms per square

Ω/□

uniformly doped material w/ resistivity $\rho=\frac{1}{\sigma}$

σ = conductivity $= q(\mu_n n+\mu_p p)$

e.g.,

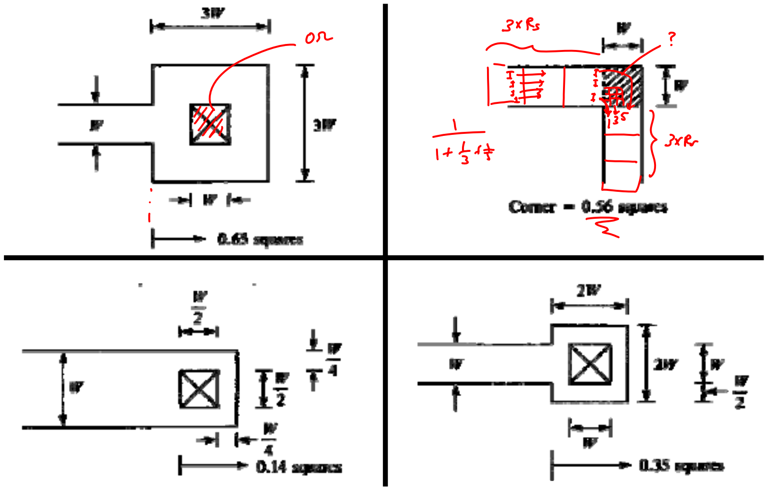


→ 5 □'s of material

$\therefore R=R_s\times 5$

- What if the trace is non-uniform? (e.g., a corner, contains a contact, etc.)

Squares From Non-Uniform Traces



Sheet Resistance of a Diffused Junction

- For diffused layers:

$$R_s=\frac{\bar{\rho}}{x_j}=\left[\int_o^{x_j}\sigma(x)dx\right]^{-1}=\left[\int_o^{x_j}q\mu N(x)dx\right]^{-1}$$

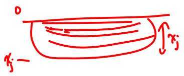
Sheet resistance

Effective resistivity

Majority carrier mobility

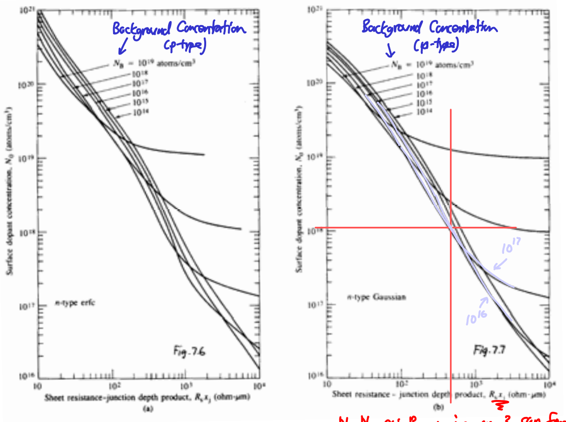
Net impurity concentration

[extrinsic material]



- This expression neglects depletion of carriers near the junction, x_j → thus, this gives a slightly lower value of resistance than actual
- Above expression was evaluated by Irvin and is plotted in "Irvin's curves" on next few slides
  - Illuminates the dependence of R_s on x_j, N_o (the surface concentration), and N_B (the substrate background conc.)

Irvin's Curves (for n-type diffusion)



N_o, N_B, x_j, R_s → given any 3, can find the 4th!

Example.

Given:

p-type

N_B = 3×10^{16} cm^{-3}

N_o = 1.1×10^{18} cm^{-3}

(n-type Gaussian)

x_j = 2.77 μm

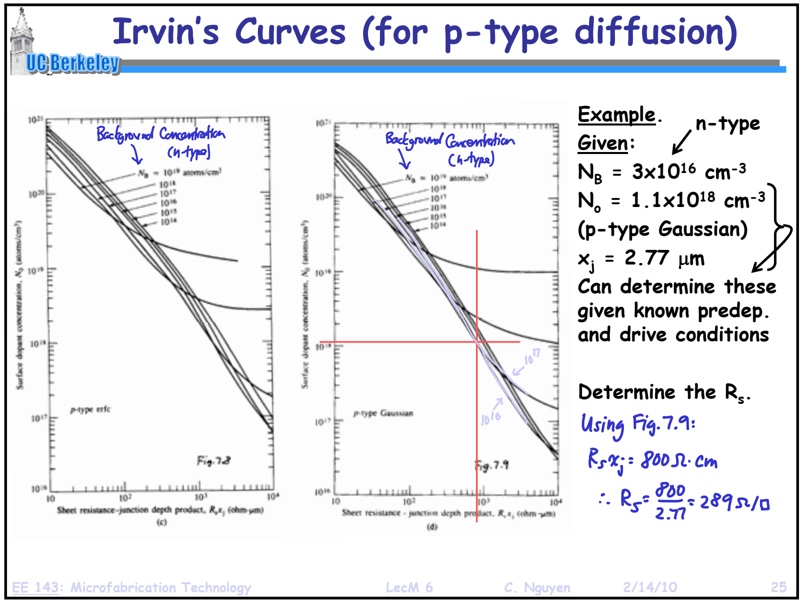
Can determine these given known predep. and drive conditions

Determine the R_s.

Using Fig. 7.7:

$R_s x_j = 470\ \Omega\cdot\mu m$

$\therefore R_s=\frac{470}{2.77}=170\ \Omega/\square$



Irvin's Curves (for p-type diffusion)

Example.

Given: n-type

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$N_o = 1.1\times10^{18}$ cm^{-3}

(p-type Gaussian)

$x_j = 2.77$ μm

Can determine these given known predep. and drive conditions

Determine the R_s.

Using Fig. 7.9:

$R_s x_j = 800\,\Omega\cdot\text{cm}$

$\therefore R_s = \frac{800}{2.77} = 289\,\Omega/\square$

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