Density of Si (crystalline) $\sim 10^{22} \frac{\text{Atoms}}{\text{cm}^3}$

Lecture 6 EE 320

Feb. 10, 2014

How valence electrons in Si (4)

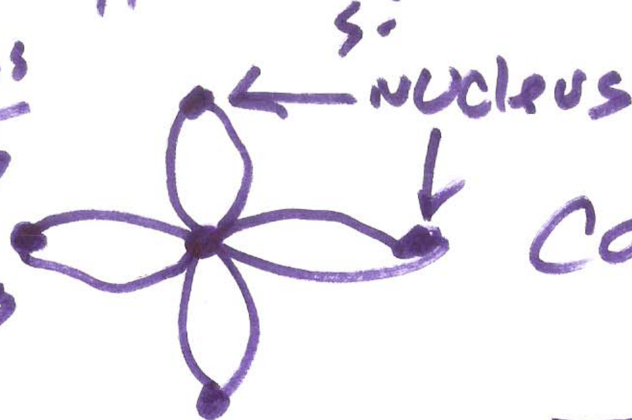
" " " P (5)

" " " B (3)

$N = 10^{11} \frac{\text{electrons}}{\text{cm}^3}$

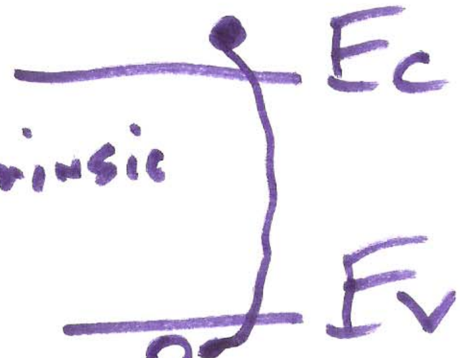
$P = 10^{11}$ holes

$N_i^2 = PN$



Covalent Bond

intrinsic



$10^{10} \frac{\text{carriers}}{\text{cm}^3}$

Si:

$N = P = 10^{10}$

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Doped Si

$N_{Si} = 10^{22}$

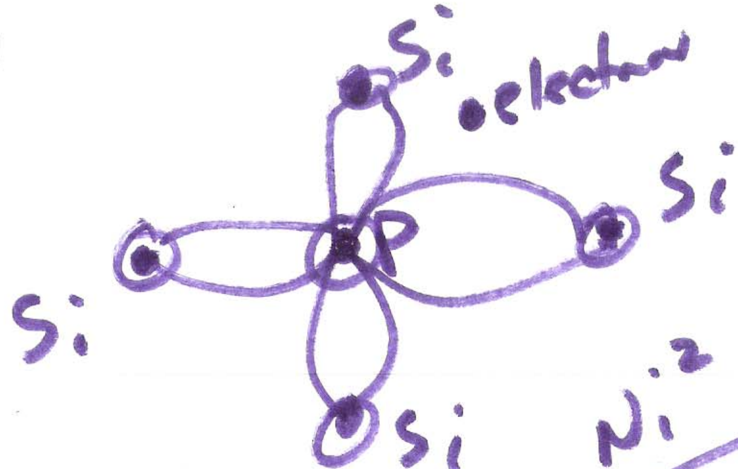
Doped ← means "add nuts to the cake"

N_D = # of donor atoms

P → Si

→ add 10^{16} phosphorous $\frac{\text{Atoms}}{\text{cm}^3}$

$np = n_i^2$



What is n?

$n = N_D + n_i$

$n \approx N_D$

assume complete ionization

$p \approx \frac{n_i^2}{N_D} = \frac{n_i^2}{N_D + n_i}$

↑ assume

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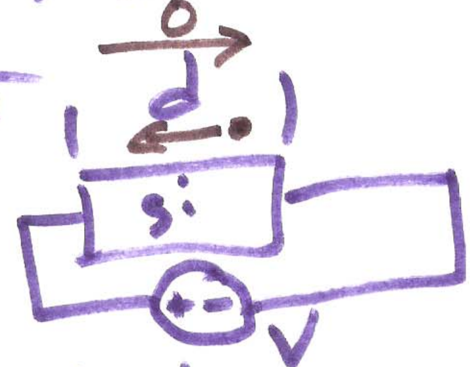
two kinds of current

1) drift current → An $\mathcal{E}$ field

2) diffusion current

$\mathcal{E} = \frac{V}{d}$



mobility

μ_n = mobility of electrons =

$\mu \rightarrow \frac{\text{velocity } cm/s}{\mathcal{E} \text{ field } V/cm}$ $cm^2/V \cdot s$

μ_n = mobility of holes

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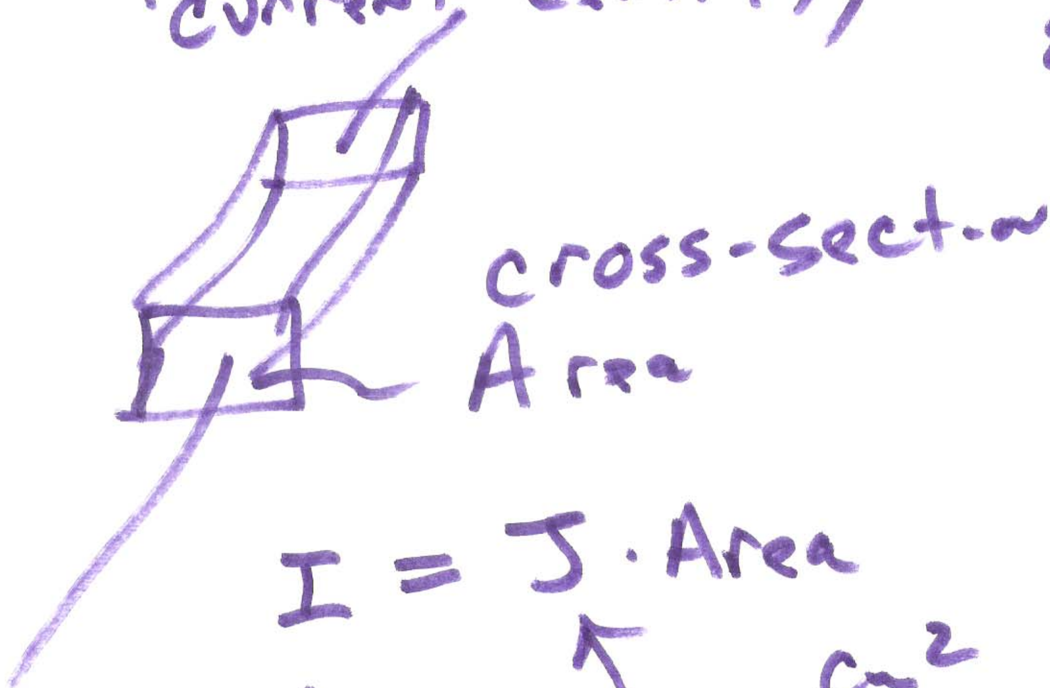
$J = Q v$ → cm/s, C/cm^3

↑ current density,

$\frac{v}{\mathcal{E}} = \mu$



$I = J \cdot \text{Area}$

Amps ; A/cm^2 ; cm^2

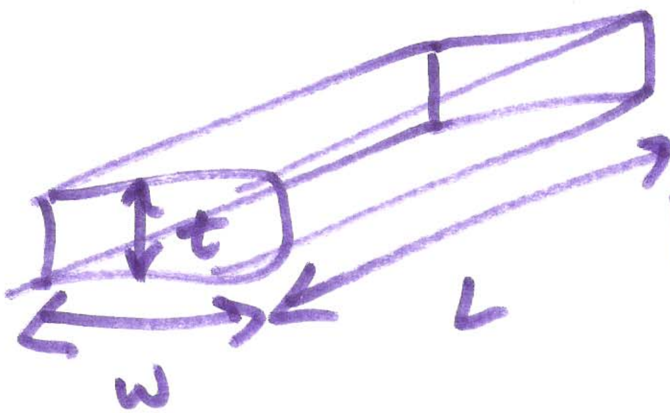
$J_N = -q \cdot n \mu_n \vec{\mathcal{E}}$

$J_P = q p \cdot \mu_p \cdot \vec{\mathcal{E}}$

$$J_T = J_n + J_p = q\mathcal{E}\cdot(\mu_n n + \mu_p \cdot p)$$

$$\sigma = \text{conductivity} = q(\mu_n n + \mu_p p)$$

$$\rho = \frac{1}{q(\mu_n \cdot n + \mu_p \cdot p)} \ \Omega\cdot\text{cm}$$



$$R = \frac{\rho}{t}\cdot\frac{L}{W}$$

Example crystalline Si doped with 10^{15} Boron $\frac{\text{atoms}}{cm^3}$

$1\,\mu m = 10^{-6}\,m = 0.0001\,cm$

$.0001\,cm$

$t = 10\,\mu m = 0.001\,cm$

$L = 200\,\mu m = 0.02$

$W = 10\,\mu m = 0.001\,cm$

$\overset{-1}{.0}\,\overset{-2\,-3\,-4\,-5}{0\,001}$

$N_D = 0$ No donor atoms

$N_A = 10^{15} \frac{\text{atoms}}{cm^3}$ (acceptor atoms)

at room estimate N_i, $N_i = 10^{10}$

$p = 10^{15} \frac{\text{holes}}{cm^3}$, assuming complete ionization & $N_A \gg N_i$

$N = \frac{N_i^2}{p} = \frac{10^{20}}{10^{15}} = 10^5 \rightarrow 10{,}000 \frac{\text{electrons}}{cm^3}$

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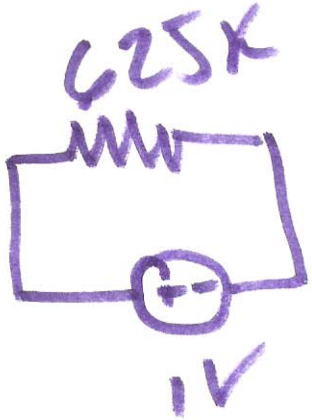
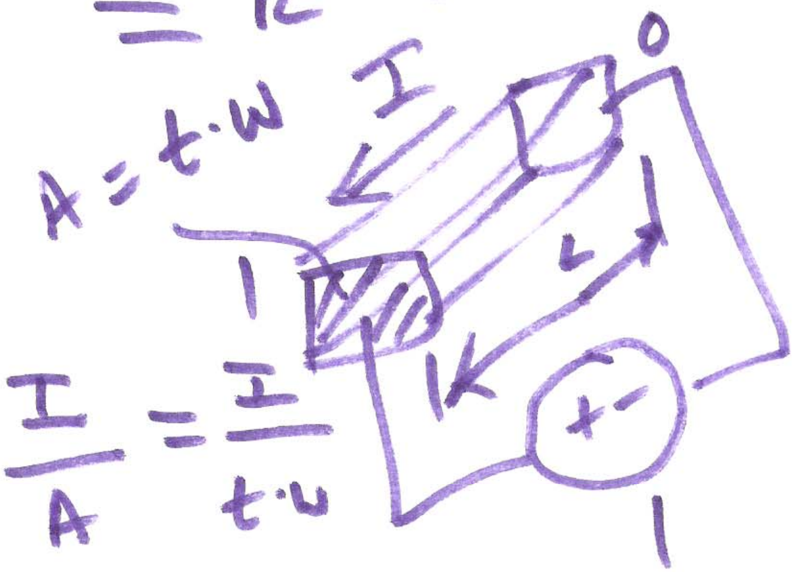
$$\rho = \frac{1}{q(n\mu_n + \mu_p p)} = \frac{1}{1.6\times10^{-19}\cdot 10^{15}\cdot 200}$$

$$\mu_p = 2800\ \frac{cm^2}{V\cdot s} \qquad = \frac{1}{320\cdot 10^{-4}}$$

$$R = \frac{\rho}{t}\cdot\frac{L}{W} = \frac{31.25\,\Omega\cdot cm}{0.001\,cm}\cdot\frac{0.02\,cm}{0.001\,cm} \qquad \frac{1}{0.0320} \approx 31.25\,\Omega\cdot cm$$

$$= R = 625K$$





$$\mathcal{E} = \frac{1\,V}{0.02\,cm} = 50\,\frac{V}{cm}$$

$$I = \frac{1}{625K}$$

$$J = \frac{I}{A} = \frac{I}{t\cdot w}$$

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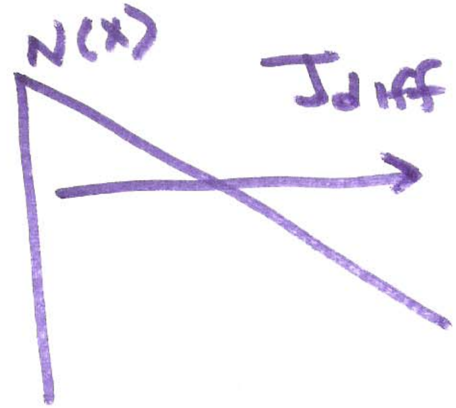
7)

Diffusion current

No Ɛ field!

for a diffusion current to flow we need a carrier variation (change)



2.49

$$J_N = q D_N \cdot \frac{\delta N}{\delta x}$$

$$\frac{\delta N}{\delta x} = \frac{10^{18}}{0.00005\ cm} = \frac{10^{18}}{5 \cdot 10^{-5}\ cm}$$

$$\frac{\delta N}{\delta x} = 0.2 \cdot 10^{23} \frac{V}{cm}$$

$$D_N = \mu_N \cdot \frac{KT}{q}$$

thermal voltage $\approx$ 26mV @ room temp

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1)