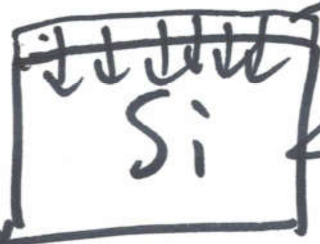
N-type



Phosphorus

(P) $\rightarrow$ Si

majority: electrons
minority: holes

intrinsic: pure Si
extrinsic: doped Si

N_D (#/cm^3)

n_i: 1.5×10^{10} /cm^3
(room temperature 25°C)
< 300 K

$\Rightarrow n_n \approx N_D$

electron n-type concentration

$$\underline{n} \cdot \underline{p} = n_i^2 \Rightarrow n_n \cdot p_n = n_i^2$$

$$p_n = \frac{n_i^2}{n_n} = \frac{n_i^2}{N_D}$$

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p-type:
majority: holes
minority: electrons

Boron

(B)° ← N_A: concentration of the acceptor atoms.

$p_p \approx N_A$ $\quad \underline{p}_p \cdot n_{\underline{p}} = n_i^2$

①

Example:

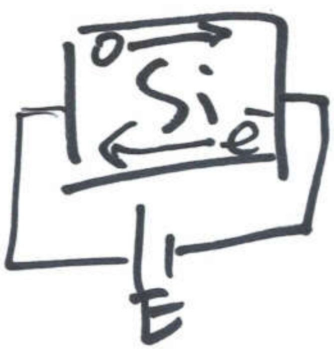
n-type Si, dopant Conc. $N_D = 10^{17}/cm^3$, Find electron and hole Conc. at room temp ($T = 300K$)

$N_D = n_n$, the electron Conc. is $10^{17}/cm^3$

$n_n \cdot p_n = n_i^2$

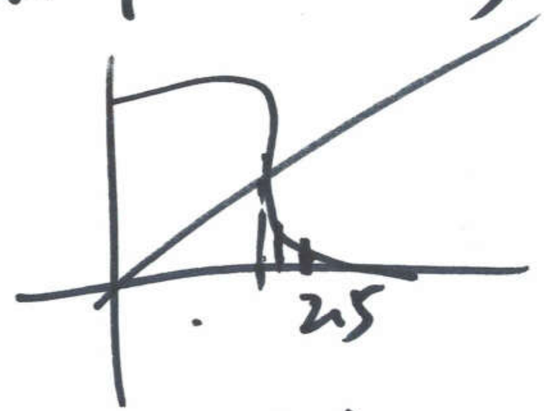
Conc. of holes $p_n = \frac{n_i^2}{n_n} = \frac{n_i^2}{N_D} = \frac{(1.5\times 10^{10}/cm^3)^2}{10^{17}/cm^3} = 2.25\times 10^3/cm^3$

- Drift current



$V_{p\text{-drift}} = \mu_p \cdot E$ (← mobility of holes) → Electric field intensity

$V_{n\text{-drift}} = \mu_n \cdot E$



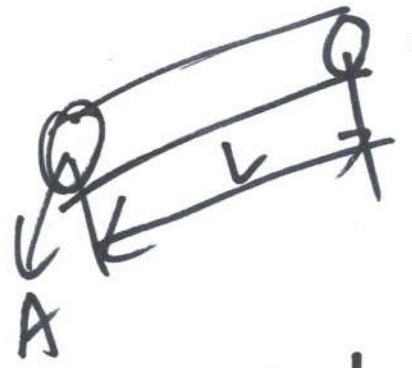
$\mu_n > \mu_p$

electrons move faster/easier than holes.

○ Resistivity:

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

Si



$R = \rho \cdot \frac{L}{A}$ (L: cm, A: cm²)

Ω

$\rho = \Omega \cdot cm$

Conductivity:

$$\sigma = \frac{1}{\rho}$$

q: magnitude of electron charge C (coulomb, C)

1.6×10^{-19} C

Example: Given: $p = n = n_i = 1.5\times10^{10}/cm^3$, $\mu_n = 1350\ cm^2/V\cdot s$, $\mu_p = 480\ cm^2/V\cdot s$, what is ρ?

$$\rho = \frac{1}{q(\mu_n \cdot n + \mu_p \cdot p)} = \frac{1}{1.6\times10^{-19}\cdot(1350\ cm^2/V\cdot s \cdot 1.5\times10^{10} + 480 \cdot 1.5\times10^{10})}$$

$$= 2.28\times10^{5}\ (\Omega\cdot cm)$$

Example: p-type, $N_A = 10^{16}/cm^3$,

$\mu_n = 1110\ cm^2/V \cdot s$, $\mu_p = 400\ cm^2/V \cdot s$

what is ρ?

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

$$n = \frac{n_i^2}{p} = \frac{n_i^2}{p_p} = \frac{n_i^2}{N_A}$$

$$= \frac{(1.5 \times 10^{10}/cm^3)^2}{10^{16}/cm^3}$$

$$= 2.25 \times 10^4/cm^3$$