Fundamentals of Microelectronics, 3rd Edition

Author: Behzad Razavi

(Solution Manual)

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Chapter 1

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There are no problem sets for this chapter

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Chapter 2

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1. (a)

$$n_i(T=300K) = 1.66\cdot10^{15}(300)^{3/2}\cdot \exp\left[\frac{-(0.66eV)}{2(1.38\cdot10^{-23}J/K)(300K)}\right]$$

$$= 2.5\cdot10^{13}\ cm^{-3}$$

$$n_i(T=600K) = 1.66\cdot10^{15}(600)^{3/2}\cdot \exp\left[\frac{-(0.66eV)}{2(1.38\cdot10^{-23}J/K)(600K)}\right]$$

$$= 4.15\cdot10^{16}\ cm^{-3}$$

Comparing these results with those in Example:

$$\frac{n_i(Ge\ @\ 300K)}{n_i(Si\ @\ 300K)} \approx 2315. \qquad \frac{n_i(Ge\ @\ 600K)}{n_i(Si\ @\ 600K)} \approx 27.$$

At higher temperature, the exponential terms approaches one, which implies that $n_i \sim T^{3/2}$, independent of bandgap energy, Eg.

(b) For any doped material, $n\cdot p = n_i^2$. Assuming at $T=300K$,

$$p = 5\cdot10^{16} cm^{-3}$$

$$n = [n_i(T=300K)]^2/p = \frac{(2.5\cdot10^{13}cm^{-3})^2}{5\cdot10^{16}cm^{-3}} = 1.25\cdot10^{10}cm^{-3}$$

2. (a) Mobility of electrons in Si $= 1350\ cm^2/V\text{-}s$
Mobility of holes in Si $= 480\ cm^2/V\text{-}s$

$$\Rightarrow \text{velocity of electrons} = \mu_n E = \left(1350\ \frac{cm^2}{V\text{-}s}\right)\left(0.1\ \frac{V}{\mu m}\right)$$

$$= 1.35 \cdot 10^4\ m/s$$

$$\text{velocity of holes} = \mu_p E = \left(480\ \frac{cm^2}{V\text{-}s}\right)\left(0.1\ \frac{V}{\mu m}\right)$$

$$= 4.8 \cdot 10^3\ m/s$$

(b) Given $E = 0.1\ V/\mu m$ hole current negligible
$\mu_n = 1350\ cm^2/V\text{-}s$ $\mu_p = 480\ cm^2/V\text{-}s$

$$J_{tot} = 1\ mA/\mu m^2 = q[\mu_n n E + \mu_p p E] \approx q\mu_n n E$$

$$\therefore n = \frac{J_{tot}}{q\mu_n E} = \frac{1\ mA/\mu m^2}{(1.6 \cdot 10^{-19} C)(1350\ cm^2/V\text{-}s)(0.1\ V/\mu m)}$$

$$= 4.6 \cdot 10^{17}\ cm^{-3}$$

3. Given $L = 0.1\ um$ $A = (0.05um)^2$ $V = 1V$

$\mu_n = 1350\ cm^2/V\text{-}s$ $\mu_p = 480\ cm^2/V\text{-}s$

$n = 10^{17}\ cm^{-3}$ (assuming n-type dopant)

(a) $$n_i(T=300k) = 5.2\cdot 10^{15}(300)^{3/2} \exp\left[\frac{-1.12eV}{2(1.38\cdot 10^{-23} J/k)(300k)}\right]$$

$$= 1.08\cdot 10^{10}\ cm^{-3}$$

$p = n_i^2/n = 1.17\cdot 10^3\ cm^{-3}$ $E = V/L = 10\ V/um$

$$\therefore I_{tot} = A\cdot J_{tot} = A\cdot q[\mu_n n + \mu_p p]E$$

$$= A\cdot q[\mu_n n + \mu_p (n_i^2/n)]E$$

$$= (0.05um)^2(1.6\cdot 10^{-19}C)\left[1350\frac{cm^2}{V\text{-}s}(10^{17}cm^{-3}) + 480\frac{cm^2}{V\text{-}s}(1.17\cdot 10^3\ cm^{-3})\right]$$

$$\cdot (10\ V/um)$$

$\Rightarrow I_{tot} \approx 0.054\ mA$

(b) @ 400K : $n_i = 3.7 \cdot 10^{12}\ cm^{-3}$

$$\underline{p} = n_i^2/n = 1.4 \cdot 10^{8}\ cm^{-3}$$

$$\underline{E} = 10\ V/um$$

$$\therefore I_{tot} = A \cdot q\left[\mu_n n + \mu_p (n_i^2/n)\right] E$$

$$= (0.05\,um)^2 (1.6 \cdot 10^{-19} C)\left[1350 \frac{cm^2}{V\text{-}s}(10^{17} cm^{-3}) + 480 \frac{cm^2}{V\text{-}s}(1.4 \cdot 10^{8} cm^{-3})\right]$$

$$\cdot (10\ V/um)$$

$$\Rightarrow I_{tot} \approx 0.054\ mA.$$