MSE/EE 5201 Phys of Semiconductor Devices HW# 4 ANSWERS

Problem 3.1 (10 points)

$$r = \frac{k \cdot n^2 \hbar^2}{m q^2}$$

here $K = 4\pi \varepsilon_0 \varepsilon_r = 4\pi \times 8.85 \times 10^{-12}\ C^2/N\cdot m^2 \times 11.8$

$n^2 = 1^2 = 1$

$\hbar^2 = \left(\frac{h}{2\pi}\right)^2 = \frac{(6.63 \times 10^{-34})^2}{4\pi^2}\ J^2 \cdot s^2$

$m = 0.26\ m_0 = 0.26 \times 9.1 \times 10^{-31}\ kg$

$q = e = 1.60 \times 10^{-19}\ C$

So, $r = 2.41 \times 10^{-9}\ m = 24.1\ \text{Å}$

$2r = 48.2\ \text{Å} \gg a\ (5.43\ \text{Å})$

the covalent bonding model is invalid in this case.

* * *

Problem 3.2 (10 points)

At $300°K$ $\quad k_B T = \frac{1.38 \times 10^{-23}\ J/K \times 300\ K}{1.60 \times 10^{-19}\ C} = 0.0258\ eV$

The Fermi function

$$f(E) = \frac{1}{1 + \exp\left(\frac{E - E_F}{0.0258}\right)} = \frac{1}{1 + \exp\left(\frac{E - 1}{0.0258}\right)}$$

(calculation and graph omitted)

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Problem 3.7 (20 points)

$$n_o = N_c \exp\left[-\frac{E_c - E_F}{kT}\right] \quad \cdots\cdots (3\text{-}15)$$

$$p_o = N_v \exp\left[-\frac{E_F - E_v}{kT}\right] \quad \cdots\cdots (3\text{-}19)$$

$$n_i = N_c \exp\left[-\frac{E_c - E_i}{kT}\right] \quad \cdots\cdots (3\text{-}21)$$

$$p_i = N_v \exp\left[-\frac{E_i - E_v}{kT}\right] \quad \cdots\cdots (3\text{-}21)$$

Then

$$\frac{n_o}{n_i} = \frac{N_c \exp\left[-\frac{E_c - E_F}{kT}\right]}{N_c \exp\left[-\frac{E_c - E_i}{kT}\right]} = \exp\left[\frac{-E_c + E_F}{kT} - \frac{-E_c + E_i}{kT}\right]$$

$$n_o = n_i \exp\left[\frac{E_F - E_i}{kT}\right]$$

Similarly

$$p_o = p_i \exp\left[\frac{E_i - E_F}{kT}\right]$$

From $n_o = n_i \exp\left[\frac{E_F - E_i}{kT}\right]$ we can get

$$E_F - E_i = kT \ln \frac{n_o}{n_i}$$

For $n_o = 10^{16}\ \text{cm}^{-3}$ $\quad n_i = 1.5 \times 10^{10}\ \text{cm}^{-3}$ (300°K)

$$E_F - E_i = 0.0258\ \text{eV} \times \ln \frac{10^{16}}{1.5 \times 10^{10}} = 0.347\ \text{eV}$$