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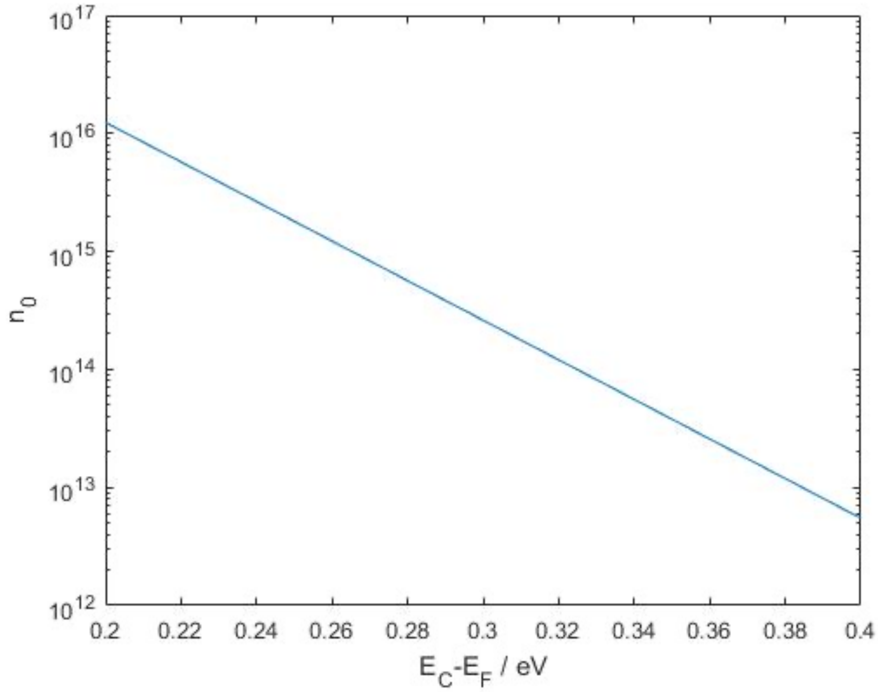
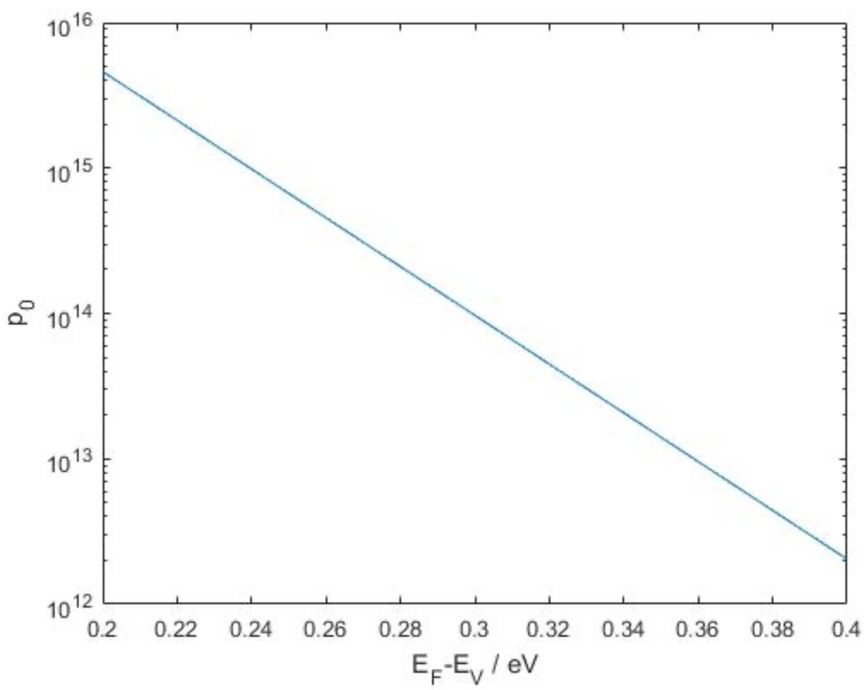
1.(a). $n_0 = N_c \exp\left(\frac{E_F - E_C}{kT}\right) = (2.8\times10^{19}\ cm^{-3}) \exp\left(\frac{E_F - E_C}{0.0259}\right)$



(b). $p_0 = N_v \exp\left(\frac{E_v - E_F}{kT}\right) = (1.04\times10^{19}\ cm^{-3}) \exp\left(\frac{E_V - E_F}{0.0259}\right)$



2. (a). $E_{Fi} - E_{midgap} = \frac{3}{4} kT \ln\left(\frac{m_p^*}{m_n^*}\right) = \frac{3}{4} \times 0.0259 \ln\left(\frac{0.70}{1.21}\right) = -0.0106$ eV

(b). $E_{Fi} - E_{midgap} = \frac{3}{4} \times 0.0259 \ln\left(\frac{0.75}{0.08}\right) = 0.0435$ eV

3. (a). $p_0 = N_v \exp\left(\frac{E_v - E_F}{kT}\right) \Rightarrow E_F - E_v = -kT \ln\left(\frac{p_0}{N_v}\right)$

$$= -0.0259 \ln\left(\frac{5\times10^{15}}{1.04\times10^{19}}\right)$$

$$= 0.198 \text{ eV}$$

(b). $E_c - E_F = E_g + E_v - E_F = 1.12 - 0.198 = 0.922$ eV

(c). $n_0 = N_c \exp\left(\frac{E_F - E_c}{kT}\right) = 2.8 \times 10^{19} \exp\left(\frac{-0.922}{0.0259}\right) = 9704 \text{ cm}^{-3}$

(d). holes

(e). $E_{Fi} - E_F = kT \ln\left(\frac{p_0}{n_i}\right) = 0.0259 \ln\left(\frac{5\times10^{15}}{1.5\times10^{10}}\right) = 0.329$ eV

4. (a) (i). $n_0 = \frac{N_d - N_a + \sqrt{(N_d - N_a)^2 + 4n_i^2}}{2} = 2.0 \times 10^{15} \text{ cm}^{-3}$

$$p_0 = \frac{n_i^2}{n_0} = \frac{(2.4\times10^{13})^2}{2.0\times10^{15}} = 2.8\times10^{11} \text{ cm}^{-3}$$

(ii). $n_0 = \frac{N_d - N_a + \sqrt{(N_d - N_a)^2 + 4n_i^2}}{2} = 1.92\times10^{11} \text{ cm}^{-3}$

$$p_0 = \frac{n_i^2}{n_0} = 3.0 \times 10^{15} \text{ cm}^{-3}$$

(b). (i). $n_0 = \frac{N_d - N_a + \sqrt{(N_d - N_a)^2 + 4n_i^2}}{2} = 2\times10^{15} \text{ cm}^{-3}$

$$p = \frac{n_i^2}{n_0} = \frac{(1.8\times10^{6})^2}{2\times10^{15}} = 1.62\times10^{-3} \text{ cm}^{-3}$$

(ii). $p_0 = \frac{N_a - N_d}{2} + \sqrt{\left(\frac{N_a - N_d}{2}\right)^2 + n_i^2} = 3\times10^{15} \text{ cm}^{-3}$

$$n_0 = \frac{n_i^2}{p_0} = 1.08\times10^{-3} \text{ cm}^{-3}$$

(c). There is about 1.08 minority carrier in volume of 10^{3} cm^3

5. (a). It is p-type.

majority: $P_o = \frac{N_a - N_d}{2} + \sqrt{\left(\frac{N_a - N_d}{2}\right)^2 + n_i^2} = 1.5 \times 10^{16}$ cm^{-3}

minority: $n_o = \frac{n_i^2}{P_o} = 1.5 \times 10^4$ cm^{-3}

(b). Borons should be added.

The concentration should be $5 \times 10^{16} - 1.5 \times 10^{16} = 3.5 \times 10^{16}$ cm^{-3}

new $n_o = \frac{n_i^2}{P_o} = 4500$ cm^{-3}

6 (a). $E_{Fi} - E_{midgap} = \frac{3}{4} kT \ln\left(\frac{m_p^*}{m_n^*}\right) = \frac{3}{4} \times 0.0259 \ln 10 = 0.0447$ eV

(b). (i). It is p-type, therefore, acceptor atoms are added

(ii). $P_o = n_i \exp\left(\frac{E_{Fi} - E_F}{kT}\right) = 10^5 \exp\left(\frac{0.0447 + 0.45}{0.0259}\right) = 1.973 \times 10^{13}$ cm^{-3}

7. (a). $N_d = 0.05 \times 7 \times 10^{15} = 3.5 \times 10^{14}$ cm^{-3}

$N_a = 0.95 \times 7 \times 10^{15} = 6.65 \times 10^{15}$ cm^{-3}

(b). p-type

(c). $P_o = N_a - N_d = 6.3 \times 10^{15}$ cm^{-3}

$n_o = \frac{n_i^2}{P_o} = 5.14 \times 10^{-4}$ cm^{-3}

(d). $E_F - E_{Fi} = -kT \ln\left(\frac{P_o}{n_i}\right) = -0.569$ eV