EE 362 Electronic, Magnetic, & Optical Properties of Materials
Quiz 4 (Spring 2024)

Name Key A

Instructions: Open book & notes. Place answers in indicated spaces. Show all work. Use 4-5 significant figures.

A silicon carbide (SiC) semiconductor has a bandgap of 2.36 eV and effective electron and hole masses of $0.72m_0$ and $0.6m_0$ respectively. A sample of the SiC, left on the car dash by a forgetful student on a sunny day, is at 335 K. First, find k_BT (eV & J) for this sample. Then, calculate the effective density of states function in the conduction and valence bands (cm^{-3}) as well as the intrinsic carrier concentration (cm^{-3}).

$$k_BT = 8.617333\times10^{-5}(335) = \underline{0.028868\ eV}$$

$$= 1.380649\times10^{-23}(335) = \underline{4.62517\times10^{-21}\ J}$$

$$(4.10)\quad N_c = 2\left[\frac{2\pi m_n^* k_BT}{h^2}\right]^{3/2} = 2\left[\frac{2\pi\, 0.72(9.1093837\times10^{-31})4.6252\times10^{-21}}{(6.62607015\times10^{-34})^2}\right]^{3/2}$$

$$= 1.80907\times10^{26}\ \#/m^3 = \underline{1.80907\times10^{19}\ \#/cm^3}$$

$$(4.18)\quad N_v = 2\left[\frac{2\pi m_p^* k_BT}{h^2}\right]^{3/2} = \left(\frac{m_p^*}{m_n^*}\right)^{3/2} N_c = \left(\frac{0.6}{0.72}\right)^{3/2} N_c$$

$$= 1.37621\times10^{26}\ \#/m^3 = \underline{1.37621\times10^{19}\ \#/cm^3}$$

$$(4.23)\quad n_i^2 = N_c N_v e^{\frac{-E_g}{k_BT}} = (1.80907\times10^{19})(1.3762\times10^{19})e^{\frac{-2.36}{0.028868}}$$

$$= 7.79884\times10^{2}$$

$$n_i = \sqrt{779.884} = \underline{27.9264\ \#/cm^3}$$

↑ Bigger bandgap ⇒ lower n_i

k_BT = $0.02887\ eV$ = $4.6252\times10^{-21}\ J$ eff. dens. states func.$_{cond}$ (N_c) = $1.8091\times10^{19}\ \#/cm^3$

N_v = eff. dens. of states func.$_{val}$ = $1.3762\times10^{19}\ \#/cm^3$ intrinsic carrier conc. (n_i) = $27.9264\ \#/cm^3$

EE 362 Electronic, Magnetic, & Optical Properties of Materials
Quiz 4 (Spring 2024)

Name Key B

Instructions: Open book & notes. Place answers in indicated spaces. Show all work. Use 4-5 significant figures.

A silicon carbide (SiC) semiconductor has a bandgap of 2.36 eV and effective electron and hole masses of $0.72m_0$ and $0.6m_0$ respectively. A sample of the SiC, dropped by a clumsy graduate student into boiling water, is at 370 K. First, find k_BT (eV & J) for this sample. Then, calculate the effective density of states function in the conduction and valence bands (cm^{-3}) as well as the intrinsic carrier concentration (cm^{-3}).

$$k_BT = 8.617333 \times 10^{-5}(370) = \underline{0.031884\ eV}$$

$$= 1.380649 \times 10^{-23}(370) = \underline{5.1084 \times 10^{-21}\ J}$$

$$(4.10)\ N_c = 2\left[\frac{2\pi m_n^* k_BT}{h^2}\right]^{3/2} = 2\left[\frac{2\pi\, 0.72(9.1093837 \times 10^{-31})5.1084 \times 10^{-21}}{(6.62607015 \times 10^{-34})^2}\right]^{3/2}$$

$$= 2.09987 \times 10^{26}\ \#/m^3 = \underline{2.09987 \times 10^{19}\ \#/cm^3}$$

$$(4.18)\ N_v = 2\left[\frac{2\pi m_p^* k_BT}{h^2}\right]^{3/2} = \left(\frac{m_p^*}{m_n^*}\right)^{3/2} N_c = \left(\frac{0.6}{0.72}\right)^{3/2} 2.0999 \times 10^{26}$$

$$= 1.59742 \times 10^{26}\ \#/m^3 = \underline{1.5974 \times 10^{19}\ \#/cm^3}$$

$$(4.23)\ n_i^2 = N_c N_v e^{\frac{-E_g}{k_BT}} = (2.0999 \times 10^{19})(1.5974 \times 10^{19}) e^{\frac{-2.36}{0.031884}}$$

$$= 2.3988 \times 10^6$$

$$n_i^2 = \sqrt{2.3988 \times 10^6} = 1548.81\ \#/cm^3$$

k_BT = $\underline{0.03188\ eV}$ = $\underline{5.1084 \times 10^{-21}\ J}$ eff. dens. states func. $_{cond}$ (N_c) = $\underline{2.0999 \times 10^{19}\ \#/cm^3}$

eff. dens. of states func. $_{val}$ (N_v) = $\underline{1.5974 \times 10^{19}\ \#/cm^3}$ intrinsic carrier conc. (n_i) = $\underline{1548.8\ \#/cm^3}$