Physics-2 "15B11PH211" Tutorial 10 (Solution)

(1) from mass action law $n \cdot p = n_i^2$

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

$$= \frac{2.25 \times 10^{20}}{2.25 \times 10^{15}}$$

$$= 10^5 /cm^3$$

(2) At 300K $2kT = 2 \times 8.614 \times 10^{-5} \times 300 eV = 0.052 eV$

Now intrinsic concentration of charge carrier is

$$n_i = 2\left(\frac{2\pi kT}{h^2}\right)^{3/2} (m_e^* m_h^*)^{3/4} \exp\left(-\frac{E_g}{2kT}\right)$$

$$\exp\left(\frac{E_g}{0.052}\right) = \frac{1.713 \times 10^{24}}{2.29 \times 10^{18}} = 0.748 \times 10^6$$

or $$E_g = 0.052\,[\ln(0.748) + 6\ln 10]$$

$$E_g = 0.7 eV$$

(3) Given $E_c - E_F = 0.44 eV$ below conduction band, $T = 300K$, $kT = 0.026 eV$, $N_D' = 5N_D$, $E_c - E_F' = ?$

For an n-type semiconductor, the electron density is given by

$$n = N_D = N_c \exp\left(-\frac{E_c - E_F}{kT}\right)$$

ll'y $$n' = 5N_D = N_c \exp\left(-\frac{E_c - E_F'}{kT}\right)$$

Now $$\exp\left(-\frac{E_c - E_F'}{kT}\right) = 5 \exp\left(-\frac{E_c - E_F}{kT}\right)$$

$$\exp\left(-\frac{E_c - E_F'}{kT} + \frac{E_c - E_F}{kT}\right) = 5$$

$$E_c - E_F' = E_c - E_F - kT\ln 5$$

$$= 0.44 - 0.026 \times \ln 5$$

$$= 0.398 eV$$

⑥ Given-

$l = 0.2\,cm = 0.2 \times 10^{-2}\,m,$

$b = 0.12\,cm = 0.12 \times 10^{-2}\,m,$

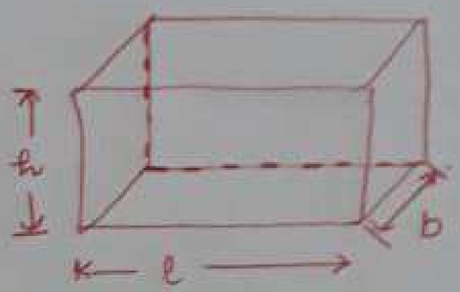
$h = 0.2\,cm = 0.02 \times 10^{-2}\,m$

$V_a = 1.0$ Volts

$I_x = 2.5 \times 10^{-3}\,A$

$B_z = 0.5\,T$

$n = ?$



$$R_H = \frac{E_y}{J_x B_z} \quad \text{where } E_y = \frac{V_H}{h} \ \& \ J_x = \frac{I_x}{bh}$$

$$\therefore R_H = \frac{V_H b}{I_x B_z} = -\frac{1}{ne} \quad (\text{for } n\text{-type})$$

$$= -\frac{1}{pe} \quad (\text{for } p\text{-type})$$

Assuming the charge carrier to be electrons

$$n = \frac{I_x B_z}{V_H b e} = \frac{2.5 \times 10^{-3} \times 0.5}{10^{-2} \times 0.12 \times 10^{-2} \times 1.6 \times 10^{-19}}$$

$$= 6.5 \times 10^{20}\,/m^3$$

Now $E_x = \frac{V_a}{l}$, $\therefore \sigma_x = \frac{J_x}{E_x} = \frac{I_x/bh}{V_a/l} = \frac{I_x l}{bhV_a}$

$$= \frac{2.5 \times 10^{-3} \times 0.2 \times 10^{-2}}{0.12 \times 10^{-2} \times 0.02 \times 10^{-2} \times 1}$$

$$= 20.8\,\Omega^{-1} m^{-1}$$

Hence $\mu_e = \frac{\sigma_x}{ne} = \frac{20.8}{6.5 \times 10^{20} \times 1.6 \times 10^{-19}}$

$$= 0.2\,m^2 V^{-1} s^{-1}$$

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(4) Given- ~~[illegible]~~ $n_i = 1.5\times10^{16}/m^3$, $\mu_e = 0.13\,m^2V^{-1}s^{-1}$, $\mu_h = 0.05\,m^2V^{-1}s^{-1}$, impurity atom = 1 atom/10^8 silicon atoms, density (si) = $2.33\times10^3\,Kg/m^3$, atomic weight (si) = 28.09, $\sigma_i = ?$, $\sigma_{ex} = ?$

$$\sigma_i = n_i e(\mu_e + \mu_h)$$
$$= 0.432\times10^{-3}\,\Omega^{-1}m^{-1}$$

No. of Si atoms per unit volume is given by

$$n = \frac{\rho N}{M} = \frac{2.33\times10^3\times6.026\times10^{26}}{28.09}$$

$$= 5\times10^{28}/m^3$$

Now density of donor atoms (impurity) will be

$$N_D = \frac{5\times10^{28}}{10^8} = 5\times10^{20}/m^3$$

Therefore the extrinsic conductivity

$$\sigma_{ex} = N_D e \mu_e$$
$$= 5\times10^{20}\times1.6\times10^{-19}\times0.13$$
$$= 10.4\,\Omega^{-1}m^{-1}$$

(5) Given: $E = 100\,V/m$, $R_H = -0.0125\,m^3/c$, sample is n-type semiconductor $\mu_e = 0.36\,m^2V^{-1}s^{-1}$. $J = ?$

For n-type semiconductor, the Hall Coefficient is

$$R_H = \frac{1}{ne} \quad \text{or} \quad n = \frac{1}{eR_H} = 5\times10^{20}/m^3$$

Further, electron conductivity is given by $\sigma_e = ne\mu_e$

& $\sigma_e = J/E$

Therefore $J = \sigma_e E$

$$= ne\mu_e E$$
$$= 5\times10^{20}\times1.6\times10^{-19}\times0.36\times100$$
$$= 2880\,A/m^2$$

Teacher's Signature :