① Find the conductivity and resistivity of an intrinsic semiconductor at temperature of 300°K. It is given that

$n_i = 2.5 \times 10^{13} /cm^3$

$\mu_n = 3800\ cm^2/V\text{-}s$

$\mu_p = 1800\ cm^2/V\text{-}s$

$q = 1.6 \times 10^{-19}\ C$

sol^n

$\sigma_i = n_i e (\mu_e + \mu_n)$

$= 2.5 \times 10^{13} \times 1.6 \times 10^{-19} (3{,}800 + 1800)$

$= 0.0224\ S/cm.$

intrinsic resistivity

$\rho_i = \frac{1}{\sigma_i} = \frac{1}{0.0224} = 44.64\ \Omega\text{-}cm.$

② The intrinsic resistivity of germanium at 300°K is 0.47 Ω-m. The electron mobility at 300°K in germanium is 0.39 ~~×10~~ $m^2/V\text{-}s$. The hole mobility μ_h at 300°K in germanium is 0.19 $m^2/V\text{-}s$. ~~The elect~~ Calculate the density of electrons in the intrinsic material. Also calculate the drift velocity of holes and electrons for an electric field ($E = 10^4\ V/m$).

sol^n

intrinsic resistivity $(\rho_i) = 0.47\ \Omega\text{-}m$

intrinsic conductivity $(\sigma_i) = \frac{1}{\rho_i}$

$= \frac{1}{0.47} = 2.12766\ S/m$

$\mu_e = 0.39\ m^2/V\text{-}s$

$\mu_h = 0.19\ m^2/Vs$

$e = 1.6 \times 10^{-19}\ C$

$\sigma_i = n_i e (\mu_e + \mu_h)$

$n_i = \frac{\sigma_i}{e(\mu_e + \mu_h)}$

$= \frac{2.12766}{1.6 \times 10^{-19} (0.39 + 0.19)}$

$\boxed{n_i = 2.293 \times 10^{19} / m^3}$ ANS

$E = 10^4\ V/m$

$v_n = \mu_e E = 0.39 \times 10^4$

$\boxed{v_n = 3900\ m/s}$ ANS

~~$v_{h} = 0.19 \times 10^4$~~

$v_h = \mu_h E = 0.19 \times 10^4$

$\boxed{v_h = 1900\ m/s}$ ANS

③ The intrinsic carrier concentration for silicon at room temp. is $1.5\times10^{10}/cm^3$. If the mobility of electrons and holes are $1300\ cm^2/V\text{-}s$ and $450\ cm^2/V\text{-}s$ respetively. what is the conductivity of silicon (intrinsic) at $300^\circ K$? If silicon is doped with 10^{18} boron atoms per cc, what is its conductivity.

Solⁿ:

$n_i = 1.5\times10^{10}/cm^3$

$\mu_h = 450\ cm^2/V\text{-}s$

$\mu_e = 1300\ cm^2/V\text{-}s$

$\sigma_i = n_i e(\mu_e+\mu_h)$

$= 1.5\times10^{10}\times1.6\times10^{-19}(1300+450)$

$\boxed{\sigma_i = 4.2\times10^{-6}\ S/cm.}$ Ans.

After Doping

$N_A = 10^{18}/cm^3$

$\sigma_p = N_A e \mu_h$

$= 10^{18}\times1.6\times10^{-19}\times450$

$\boxed{\sigma_p = 72\ S/cm.}$ Ans.

④ Find the conductivity of intrinsic germanium at $300^\circ K$. If donor type impurity is added to the extent of 1 impurity atom in 10^7 germanium atoms, find the conductivity.

Given ~~that~~

$n_i = 2.5\times10^{13}/cm^3$

$\mu_h = 1800\ cm^2/V\text{-}s$

$\mu_e = 3800\ cm^2/V\text{-}s$

Concentration of Ge atoms $= 4.41\times10^{22}/cm^3$

Solⁿ

$\sigma_i = n_i e(\mu_e+\mu_h)$

$= 2.5\times10^{13}\times1.6\times10^{-19}(3800+1800)$

$\boxed{\sigma_i = 0.0224\ S/cm}$ Ans.

No. of Ge atoms/cm³ $= 4.41\times10^{22}/cm^3$

$$N_D = \frac{4.41\times10^{22}}{10^7} = 4.41\times10^{15}/cm^3$$

Concentration of electrons.

$n \simeq N_D = 4.41\times10^{15}/cm^3$

$$p = \frac{n_i^2}{N_D} = \frac{(2.5\times10^{13})^2}{4.41\times10^{15}}$$

$\boxed{p = 1.417\times10^{11}/cm^3}$

$\sigma_e = e N_D \mu_e$

$= 1.6\times10^{-19}\times4.41\times10^{15}\times3800$

$\boxed{\sigma_e = 2.68\ S/cm}$ Ans.

(5)

A pd (Potential difference) of 10V is applied longitudinally to a rectangular specimen of intrinsic Ge of length 25 mm, width 4 mm and thickness 1.5 mm. Determine at room temp.

(i) electron and hole drift velocities.

(ii) the conductivity of intrinsic germanium if intrinsic carrier density is $2.5\times10^{19}/m^3$

(iii) Total current.

Given! $\mu_e = 0.38\,m^2/Vs$, $\mu_n = 0.18\,m^2/Vs$

Sol^n (i) $E = V/l = \frac{10}{0.025}$

$= 400\ V/m.$

$v_e = \mu_e \times E = 0.38\times400$

$\boxed{v_e = 152\ m/s}$ Ans

$v_n = \mu_n \times E = 0.18\times400$

$\boxed{v_n = 72\ m/s}$ Ans

(ii) $\sigma_i = n_i e(\mu_e + \mu_n)$

$= 2.5\times10^{19}\times1.6\times10^{-19}\cdot(0.38+0.18)$

$\boxed{\sigma_i = 2.24\ S/m}$ Ans

(iii) $I = \sigma_i E a$

$= 2.24\times400\times4\times10^{-3}\times1.5\times10^{-3}$

$\boxed{I = 5.376\ mA}$ Ans

Date: 1/2/16

Tutorial - 1

① In a certain copper conductor, the current density is 2.4 A/mm² and electron density is 5×10^{28} free electrons per m³ of the copper. Determine the drift velocity of the electrons.

Solⁿ

$$J = 2.4\ A/mm^2 = 2.4 \times 10^6\ A/m^2$$

$$n = 5 \times 10^{28}$$

(charge on electron) $q = 1.6 \times 10^{-19}$ C

$$J = nqv$$

$$v = \frac{J}{nq} = \frac{2.4 \times 10^6}{1.6 \times 10^{-19} \times 5 \times 10^{28}} = 0.3 \times 10^{-3}\ m/s$$

ANS

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② A conductor material has a free electron density of 10^{24} electrons per m³. When a voltage is applied, a constant drift velocity of 1.5×10^{-2} m/s is attained by the electron. If the cross-sectional area of the material is 1 cm² calculate the magnitude of current. ~~charge~~

Solⁿ

$$n = 10^{24}$$

$$q = 1.6 \times 10^{-19}\ C.$$

$$v = 1.5 \times 10^{-2}\ m/s = 0.015\ m/s$$

$$a = 1\ cm^2 = 1 \times 10^{-4}\ m^2$$

$I = \frac{Nqv}{LA}$

$I = nqv$

$J = \sigma E$

$= \sigma E a$

$nqv a$

∴ magnitude of (I) current $= qnva = 1.6 \times 10^{-19} \times 10^{24} \times 0.015 \times 1 \times 10^{-4}$

$$= 0.24\ A$$

ANS

$nq\mu E$

$J = nqv = nev$

$$\boxed{I = nevA}$$

③. A specimen of germanium at 300°K for which the density of carriers is 2.5×10^{13} per cm3, is doped with impurity atoms such that there is one impurity atom for 10^6 germanium atoms. All the impurity atoms may be assumed ionized. The conductivity of doped material is 25.64 S/cm. carrier mobility for germanium at 300°k is 3600 cm²/V-s. For the doped material, find the electron and hole density.

<u>Solⁿ</u>

$$\sigma = 25.64 \ \cancel{S/cm} \ S/cm.$$

charge on electron $(q) = 1.602 \times 10^{-19}$ c.

mobility $\mu_e = 3600 \ cm^2/V\text{-}s$

$$\sigma_n = nq\mu_e = N_D q \mu_e \quad \text{—①}$$

$$N_D = \frac{\sigma_n}{q\mu_e} = \frac{25.64}{1.602 \times 10^{-19} \times 3600}$$

$$= 4.45 \times 10^{16} / cm^3$$

(i) Concentration of electron $n \simeq N_D = 4.45 \times 10^{16}/cm^3$

(ii) Concentration of hole, $P = \frac{n_i^2}{N_D} = \frac{(2.5 \times 10^{13})^2}{4.45 \times 10^{16}}$.

$$= 1.4 \times 10^{10} / cm^3$$

Ans

(4) A donor type impurity is added to the extent of 1 atom per 10^6 atoms of an intrinsic semiconductor (Silicon). Calculate

(i) Resulting donor atom concentration

(ii) Resulting mobile electron concentration

(iii) Resulting hole concentration.

(iv) Conductivity of doped silicon sample.

(v) If silicon bar is 0.5 cm long, cross-section area of $(50\times10^{-4})^2$ cm². Find its resistivity.

Concentration of silicon atoms $= 5\times10^{22}\ cm^{-3}$

~~and~~ $n_i = 1.45\times10^{10}\ cm^{-3}$

and silicon $\mu_e = 1300\ cm^2/V\text{-}s$

Solⁿ

(i) $N_D = $ (no. of silicon atom/cm³) × (donor impurity)

$$= 5\times10^{22}\times\frac{1}{10^6} = 5\times10^{16}\ /cm^3 \quad \text{ANS}$$

(ii) Mobile electron concentration $n \simeq N_D = 5\times10^{16}\ /cm^3$ ANS

(iii) Hole concentration $p = \frac{n_i^2}{N_D} = \frac{(1.45\times10^{10})^2}{5\times10^{16}} = 4.205\times10^3$ per cm³ ANS

(iv) Conductivity of doped silicon

$$\sigma = nq\mu_e = 5\times10^{16}\times1.602\times10^{-19}\times1300$$
$$= 10.413\ S/cm \quad \text{ANS}$$

(v) Resistivity $\rho = \frac{1}{\sigma} = \frac{1}{10.413} = 0.096\ \Omega\text{-cm}.$

Resistance of given semiconductor

$$R = \frac{\rho l}{a} = \frac{0.096\times0.5}{(50\times10^{-4})^2} = 1920\,\Omega$$

ANS