1.The intrinsic carrier density is 1.5×10^{16} m^{-3}. If the mobility of electron and hole are 0.13 and 0.05 m^2 V^{-1} s^{-1}, calculate the conductivity.

Solution :

Given :

$$n_i = 1.5 \times 10^{16}\ m^{-3}$$

$$\mu_e = 0.13\ m^2\ V^{-1}\ s^{-1}$$

$$\mu_h = 0.05\ m^2\ V^{-1}\ s^{-1}$$

$$\text{Conductivity} \quad \sigma = n_i e (\mu_e + \mu_h)$$

$$\sigma = 1.5 \times 10^{16} \times 1.6 \times 10^{-19} (0.13 + 0.05)$$

$$\text{Conductivity} \quad \sigma = 4.32 \times 10^{-4}\ \Omega^{-1} m^{-1}$$

2. The Intrinsic carrier density at room temperature in Ge is 2.37×10^{19} m^3 if the electron and hole mobilities are 0.38 and 0.18 m^2 V^{-1} s^{-1} respectively, calculate the resistivity.

Given:

$$n_i = 2.37 \times 10^{19}\ m^3$$

$$\mu_e = 0.38\ m^2\ V^{-1}\ s^{-1}$$

$$\mu_h = 0.18\ m^2\ V^{-1}\ s^{-1}$$

$$\text{Conductivity} \quad \sigma = n_i e (\mu_e + \mu_h)$$

$$= 2.37 \times 10^{19} \times 1.6 \times 10^{-19} (0.38 + 0.18)$$

$$= 2.1235\ \Omega^{-1}\ m^{-1}$$

$$\text{Resistivity} \quad \rho = \frac{1}{\sigma}$$

$$\rho = \frac{1}{2.1235}$$

$$\text{Resistivity} \quad \rho = 0.4709\ \Omega\ m$$

3.The Hall coefficient of certain silicon specimen was found to be -7.35×10^{-5} m^3 C^{-1} from 100 to 400 K. Determine the nature of the semiconductor. If the conductivity was found to be 200 $^{-1}$ m^{-1}. Calculate the density and mobility of the charge carrier.

Solution:

$$\text{Conductivity } \sigma = 200\ \Omega^{-1}m^{-1}$$

$$\text{Hall co-efficient } R_H = -7.35 \times 10^{-5} m^3 C^{-1} \qquad \dots(1)$$

a) Density of electrons

$$n = \frac{-1}{R_H e} \text{ (from equation (1))}$$

$$n = \frac{1}{(7.35 \times 10^{-5} \times 1.609 \times 10^{-19})}$$

$$\text{(i.e)} = 8.455 \times 10^{22} m^{-3}$$

We know Conductivity

$$\sigma = n e \mu_e$$

b) Mobility

$$\mu = \frac{\sigma}{ne} = \frac{200}{8.455 \times 10^{22} \times 1.6 \times 10^{-19}}$$

$$= 0.0147$$

$$\text{Mobility } \mu = 0.0147 m^2 v^{-1} s^{-1}$$

$$\text{Density of electrons (n)} = 8.053 \times 10^{22}\ m^{-3}$$

$$\text{Mobility } (\mu) = 0.0147 m^2 v^{-1} s^{-1}$$

4. In a P-type germanium, $n_i = 2.1 \times 10^{19}\ m^{-3}$density of boron 4.5×10^{23} atoms /m^3. The electron and hole mobility are 0.4 and 0.2 $m^2\ v^{-1}\ s^{-1}$ respectively. What is its conductivity before and after addition of boron atoms.

Solution:

Given:

Intrinsic carrier concentration $n_i = 2.1 \times 10^{19}\ m^{-3}$

Mobility of electrons $\mu_e = 0.4\ m^2\ v^{-1}\ s^{-1}$

Mobility of holes $\mu_h = 0.2\ m^2\ v^{-1}\ s^{-1}$

a) Conductivity before the addition of boron atoms

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

$$= 2.1 \times 10^{19} \times 1.6 \times 10^{-19} (0.4 + 0.2)$$

$$= 2.016\ \Omega^{-1}\ m^{-1}$$

b) Conductivity after the addition of boron atoms, Boron is a P-type impurity atom

$$\sigma = p e \mu_h$$

$$= 4.5 \times 10^{23} \times 1.6 \times 10^{-19} \times 0.2$$

$$\sigma = 14400\ \Omega^{-1}\ m^{-1}$$

5. An N-type semiconductor has hall coefficient = 4.16 × 10^{-4} m^{3} C^{-1}. The conductivity is 108 $^{-1}$ m^{-1}. Calculate its charge carrier density 'n_e'and electron mobility at room temperature.

Solution:

Given:

Given:

Hall Co-efficient R_H = $4.16 \times 10^{-4}\ m^3\ C^1$

Conductivity σ = $108\ \Omega m^{-1}$

1. For 'n' type the charge carriers density $n_e = \frac{-1}{R_H e}$ Here the negative signindicates the field direction alone.

$$n_e = \frac{3\pi}{8}\frac{-1}{R_H e}$$

$$n_e = \left[\frac{3 \times 3.14}{8}\right]\left[\frac{1}{1.6 \times 10^{-19} \times 4.6 \times 10^{-4}}\right]$$

$$n_e = 1.7690 \times 10^{22} m^{-3}$$

2. Electron mobility $\mu_e = \frac{\sigma_e}{n_e e}$

$$= \frac{108}{\left(1.7690 \times 10^{22} \times 1.6 \times 10^{-19}\right)}$$

$$\mu_e = 0.0381\ m^2 v^{-1} s^{-1}$$

6. In an N-type semiconductor, the concentration of electron is 2 × 10^{22} m^{-3} . Its electrical conductivity is 112 $^{-1}$ m^{-1}. Calculate the mobility of electrons.

Solution:

Given:

Conductivity $\sigma = 112\ \Omega^{-1}\ m^{-1}$

Carrier conerntration of electron

$$n_i = 2 \times 10^{22}\ m^{-3}$$

Hall coefficient $R_H = \frac{1}{ne}$

$$= \frac{1}{2 \times 10^{22} \times 1.6 \times 10^{-19}}$$

$$= 3.125 \times 10^{-4}\ m^{-3}\ C^{-1}$$

Mobility $\mu = \sigma R_H = 112 \times 3.125 \times 10^{-4}$

$$= 0.035\ m^2\ v^{-1}\ s^{-1}$$

7. A semiconducting crystal with 12 mm long, 5 mm wide and 1 mm thick has a magnetic density of 0.5 Wbm^{-2} applied from front to back perpendicular to largest faces. When a current of 20 mA flows length wise through the specimen, the voltage measured across its width is found to be $37\mu V$. What is the Hall coefficient of this semiconductor?

Solution:

Given:

Hall voltage $V_H = 37\ \mu V = 37 \times 10^{-6}\ V$

Breath of the material $t = 1\ mm = 1 \times 10^{-3}\ m$

Current $I_H = 20\ mA = 20 \times 10^{-3}\ A$

Magnetic flow density

$$B = 0.5\ Wbm^{-2}$$

Hall coefficient $R_H = \frac{V_H t}{I_H B}$

$$= \frac{37 \times 10^{-6} \times 1 \times 10^{-3}}{20 \times 10^{-3} \times 0.5}$$

$$R_H = 3.7 \times 10^{-6}\ C^{-1}\ m^3$$

$\therefore$ Hall coefficient $R_H = 3.7 \times 10^{-6}\ C^{-1}\ m^3$

8. Find the resistance of an intrinsic Ge rod 1 mm long, 1 mm wide and 1 mm thick at 300 K. the intrinsic carrier density 2.5 ×10^{19} m^{-3} is at 300 K and the mobility of electron and hole are 0.39 and 0.19 m^2 v^{-1} s^{-1}.

Solution:

Given:

Length of Ge rod $l = 1\text{mm} = 1 \times 10^{-3}$ m

Breath $b = 1\text{mm} = 1 \times 10^{-3}$ m

Thickness $t = 1\text{mm} = 1 \times 10^{-3}$ m

Intrinsic carrier concentration $n_i = 2.5 \times 10^{19}\ m^{-3}$

Mobility of electron $\mu_e = 0.39\ m^2\ v^{-1}\ s^{-1}$

Mobility of hole $\mu_h = 0.19\ m^2\ v^{-1}\ s^{-1}$

a) Conductivity

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

$$= 2.5 \times 10^{19} \times 1.6 \times 10^{-19}(0.39+0.19)$$

$$\sigma = 2.32\ \Omega^{-1}\ m^{-1}$$

b) Resistance

$$R = \frac{\ell}{\sigma A}$$

$$= \frac{1 \times 10^{-3}}{2.32 \times \left(1 \times 10^{-3}\ 1 \times 10^{-3}\right)} \qquad \therefore\ (A = b \times t)$$

$$R = 431\ \Omega$$

9. Hall coefficient of a specimen of depend silicon found to be 3.66 × 10^{-4} m^3 C^{-1}. The resistivity of the specimen is 8.93 × 10^{-3} m. Find the mobility and density of the charge carriers.

Solution:

Hall coefficient $R_H = 3.66 \times 10^{-4}\ m^3\ C^{-1}$

Resistivity $\rho = 8.93 \times 10^{-3}\ \Omega m$

i) Density of holes

$$n_h = \frac{1}{R_H e}$$

$$= \frac{1}{3.66 \times 10^{-4} \times 1.6 \times 10^{-19}}$$

$$n_h = 1.7076 \times 10^{22}\ m^{-3}$$

ii) Mobility of holes $\mu_n = \frac{1}{\rho n e}$

$$= \frac{1}{8.93 \times 10^{-3} \times 1.7076 \times 10^{22} \times 1.6 \times 10^{-19}}$$

$$\mu_n = 0.041\ m^2\ V^{-1}\ s^{-1}$$

10. The intrinsic carrier density of a semiconductor is 2.1 × 10^{19} m^{-3}. The electron and hole mobilities are 0.4 and 0.2 m^2 V^{-1} s^{-1} respectively. Calculate the conductivity.

Solution:

Solution:

Given data:

Intrinsic carrier concentration $n_i = 2.1 \times 10^{19}\ m^{-3}$

Mobility of electron $\mu_e = 0.4\ m^2\ V^{-1}\ s^{-1}$

Mobility of hole $\mu_h = 0.2\ m^2\ V^{-1}\ s^{-1}$

Conductivity $\sigma = n_i e (\mu_e + \mu_h)$

$= 2.1 \times 10^{19} \times 1.6 \times 10^{-19} \times (0.4 + 0.2)$

Conductivity $\sigma = 2.016\ \Omega^{-1}\ m^{-1}$

11. The electron mobility and hole mobility in Si are 0.135 $m^2\ V^{-1}\ s^{-1}$ and 0.048 $m^2\ V^{-1}\ s^{-1}$ respectively at room temperature. If the carrier concentration is $1.5 \times 10^{16}\ m^{-3}$. Calculate the resistivity of Si at room temperature.

Solution:

Given data:

Carrier concentration $n_i = 1.5 \times 10^{16}\ m^{-3}$

Mobility of electron $\mu_e = 0.135\ m^2\ V^{-1}\ s^{-1}$

Mobility of hole $\mu_h = 0.048\ m^2\ V^{-1}\ s^{-1}$

i) Electrical Conductivity σ

$$\sigma = n_i e (\mu_e + \mu_h)$$
$$= 1.5 \times 10^{16} \times 1.6 \times 10^{-19} \times (0.135 + 0.048)$$
$$\sigma = 0.4392 \times 10^{-3}\ \Omega^{-1}\ m^{-1}$$

ii) Resistivity pf silicon

$$\rho = \frac{1}{\sigma}$$
$$= \frac{1}{0.4392 \times 10^{-3}}$$
$$\rho = 2.2768\ \Omega\ m$$

ASSIGNMENT PROBLEMS

1. Find the resistance of an intrinsic germanium rod 1 cm long, 1mm wide and 1mm thick at 300 K. the intrinsic carrier density is 2.5×10^{19} / m^{-3} at 300 K and the mobility of electron and hole are 0.39 and 0.19 $m^2\ V^{-1}\ S^{-1}$. **(Ans: 4.31×10^3)**

2. In a Hall experiment a current of 25 A is passed through a long foil of silver which is 0.1mm thick and 3cm wide. If the magnetic field of flux density 0.14 Wb/m^2 is applied perpendicular to the foil, calculate the Hall voltage development and estimate the mobility of electrons in silver. The conductivity the Hall coefficient is $(-8.4 \times 10^{-11}) m^3$ / coulomb. **(Ans : 29.4 V and $57.7 \times 10^{-4}\ m^2\ V^{-1}$)**

3. The intrinsic carrier density at room temperature in Ge is $2.37 \times 10^{19}\ m^3$. If the electron and hole motilities are 0.38 and 0.18 $m^2\ V^1\ S^1$ respectively, calculate the resistivity.

(Ans : 0471   m)

4.A silicon plate of thickness 1mm, breadth 10mm, and length 100mm is placed magnetic field of 0.5 wb/m^2 acting perpendicular to its thickness. If A 10^{-2} current flows along its length, calculate the Hall voltage developed if the Hall coefficient is 3.66 × 10–4 m3 / coulomb. **(Ans : $3.7 \times 10^6\ C^{-1}\ m^3$)**

5.A N-type semiconductor has Hall coefficient = $4.16 \times 10^{-4}\ C^{-1}\ m^3$. The conductivity is 108 $ohm^{-1}\ m^{-1}$. Calculate its charge carrier density and electron mobility at room temperature. **(Ans : $0.038\ m^2\ V^{-1}\ S^{-1}$)**