NUMERICALS:-

-: Assignment III :-

1

A drift current density of $J_{drf} = 75\ A/cm^2$ is required in device using p-type silicon when an electric field of $E = 120\ V/cm$ is applied. Determine the required impurity doping concentration to achieve this specification. Assume that electrons and mobilities as $\mu_n = 1350\ cm^2/V\text{-}s$ and $\mu_p = 480 cm^2/V\text{-}s$?

Sol:-

The formula for current density is

$$J = \sigma E$$

$$J = e N_A \mu_p E$$

$$J = q N_A \mu_p E \rightarrow (1)$$

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Putting values in ① we get

$$75\ A/cm^2 = (1.6\times10^{-19})\ N_A\ (48cm^2/V\cdot s)\ (120V/cm)$$

$$N_A = \frac{75\ A/cm^2}{(1.6\times10^{-19})(120V/cm)(480cm^2/V.s)}$$

$$\boxed{N_A = 8.138\times10^{15}\,cm^{-3}}$$

② Design a semiconductor resistor with specified resistance to handle given current density. A silicon semiconductor at T=300k is initially doped with donors at a concentration of $N_d = 5\times10^{15}\,cm^{-3}$. Acceptors are to be added to form a compensated p-type material. The resistor is to have resistance of 10kΩ and handle current density of $50A/cm^2$ when 5V is applied?

Sol:-

$$I = V/R$$

$$I = 5V/10\times10^3$$

$$\boxed{I = 0.5mA}$$

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The cross sectional area, if current density is $J = 50 A/cm^2$

$A = I/J = \frac{0.5 \ mA}{50 A/cm^2}$

$\boxed{A = 10 \times 10^{-5} cm^2}$

Length of resistor will be, if E.F = 10 V/cm

$L = V/E$

$L = 5/100$

$\boxed{L = 5 \times 10^{-2} cm}$

Now conductivity of semiconductor.

$\sigma = \frac{L}{RA}$

$\sigma = \frac{5 \times 10^{-2}}{(10 \times 10^3)(10 \times 10^{-5})}$

$\boxed{\sigma = 0.5 \ \Omega cm^{-1}}$

The conductivity of a compensated P-type semi-conductor is

$\sigma = e \mu_p P$

$\sigma = e \mu_p (Na - Nd)$

Nd = given.

$Na = 1.25 \times 10^{16} cm^{-3}$, $\mu_p = 410 \ cm^2 V\text{-}s$.

putting values.

$\sigma = (1.6 \times 10^{-19})(410 \ cm^2 V\text{-}S)(1.25 \times 10^{16} - 5 \times 10^{15})$

$\boxed{\sigma = 0.492}$

↓ close to value we need.

⑥ Find the diffusion cofficents of electrons and holes of silicon single crystal at 27°C. if the mobilities of electron and holes, Day: Date: / /

are 0.17 and 0.025 m^2/Vs respectively 27°C ?

Sol:-

Temperature of silicon : T = 27°C

$T = 27+273 = 300K$

Given $\mu_e = 0.17\ m^2/V\text{-}s$

$\mu_p = 0.025\ m^2/V\text{-}s$

From einstein Diffusion eq :-

$$\frac{D_n}{\mu_n} = \frac{D_p}{\mu_p} = \frac{KT}{e} \rightarrow (1)$$

At first find D_n

$$\frac{D_n}{\mu_n} = \frac{KT}{e}$$

$$D_n = \frac{\mu_n KT}{e}$$

$\because \mu_e = \mu_n = 0.17 m^2/V\text{-}s$

$$" = \frac{(0.17)(1.38\times10^{-23})(300)}{1.6\times10^{-19}}$$

$D_n = 4.399\times10^{-3}$

$\boxed{D_n = 43.99\ cm^2/sec}$

$= 43.99 \frac{\times(10^{-2}m)^2}{sec}$

$= 43.99\ cm^2/sec$

$1m = 100cm$

$1cm = 10^{-2}m.$

Using 0.025 now

$$D_p = \frac{0.025\times1.38\times10^{-23}\times300}{1.6\times10^{-19}}$$

$D_p = 6.47\times10^{-4} m^2/sec$

$\boxed{D_p = 6.47 cm^2/sec.}$

(7) In a semiconductor, the effective mass of electron is $0.07m_o$ and that hole is $0.4m_o$ is free from electron mass. Assuming that

average relation time for holes is half that of electron, calculate the mobility of holes when the mobility of electron is $0.8 m^2/V\text{-}S$?

Sol:-

$m_e = 0.07 m_o$

$m_h = 0.4 m_o$ where $m_o = 9.1 \times 10^{-31}$

$\mu_e = 0.8 m^{-1} V^{-1} s^{-1}$

Formula for relaxation time is $m\mu/q$

then,

$$\frac{m_h \mu_h}{q_h} = \frac{1}{2}\left(\frac{m_e \mu_e}{q_e}\right)$$

Subsitute values.

$$\frac{0.4 m_o \mu_h}{-1.6 \times 10^{-19}} = \frac{1}{2}\left(\frac{0.07 \times 0.8}{1.6 \times 10^{-19}}\right)$$

$$\mu_h = \frac{1}{2}\left(\frac{0.07 \times 0.8}{0.4}\right)$$

$$\boxed{\mu_h = 0.07 m^2 V^{-1} s^{-1}}$$

(4) Calculate the position of Fermi Energy level E_F and conductivity at 300k for germanium crystal containing 5×10^{22} arsenic atoms/m^3. Also Calculate the conductivity if the mobility of electron is $0.39 \ m^2/V\text{-}S$?

Sol:-

$\mu = 0.39 m^2/V\text{-}S.$

$n = 5 \times 10^{22}$ atom/m^2

$\sigma = qN\mu$

$\sigma = 1.6 \times 10^{-19} \times 5 \times 10^{22} \times 0.39$

$\boxed{\sigma = 3120..}$ "or" $\boxed{3.12 \times 10^4 \ S/m}$

$$\frac{W}{2\pi r}\left(\frac{3n}{8\pi}\right)^{3/2}$$

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$$E_f = \frac{h^2}{2\pi m}\left(\frac{3n}{8\pi}\right)^{2/3}$$

$$E_f = \frac{(6.63\times10^{-34})^2}{2\times3.14\times9.1\times10^{-31}}\left(\frac{3(5\times10^{29})}{8\times3.14}\right)^{2/3}$$

$$\boxed{E_f = 0.36\,eV.}$$

5. In an n-type semiconductor, the Fermi lies in 0.4eV below the conduction band. If the concentration of donor atoms is doubled, find the new position of fermi level, find the new position of Fermi level, Assume $k_BT = 0.03eV$?

Sol:- $E_f = 0.4eV$

→ $k_BT = 0.03eV$.

$$E_f = E_C - KT\ln\left(\frac{n_d}{n_i}\right) \rightarrow (1)$$

$$E_C = E_f + KT\ln\left(n_d/n_i\right) \rightarrow (2)$$

$E_c = (0.4eV) + (0.03\,eV)\ln \frac{n_d}{n_i}.$

~~Eee~~ $\therefore$ putting E_c in eq (1)

$E_f = (0.4ev) + (0.03ev)\ln \frac{n_d}{n_i} - KT \ln n_d/n_i$

$E_f = 0.4eV - 0.03\,eV \ln 2/10$

$\boxed{E_f = 0.379eV.}$

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3. Mobilities of electron and holes in a sample intrinsic germanium at 300K are $0.36 m^2/VS$, $0.17 m^2/VS$ respectively. If conductivity of specimen is $2.12 \Omega^{-1} m^{-1}$, compute forbidden energy gap. The variation of resistivity of intrinsic germanium with temperature is given in table.

T(K)	385	455	556	714
ρ (Ωm)	0.028	0.0061	0.0013	0.000274

Calculate band gap?

$\mu_e = 0.36 m^2/VS.$

$\mu_p = 0.17 m^2/V\text{-}S$

$\sigma = 2.12 \Omega^{-1} m^{-1}$

To Find $E_g = ?$

Sol:-

$\sigma = q n_i \mu$ where $\mu = \mu_e + \mu_p$.

$\sigma = q n_i (\mu_e + \mu_p)$.

$n_i = \dfrac{\sigma}{q(\mu_p + \mu_i)}$

$n_i = \dfrac{2.12}{(1.6 \times 10^{-19})(0.36 + 0.17)}$

$n_i = 2.5 \times 10^{19}$

$n_i = C T^{3/2} \exp(-E_g/2kT)$.

$n_i = C T^{3/2} \exp[-E_g/2kT]$.

$\exp[E_g/2kT] = \dfrac{C T^{3/2}}{n_i}$

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$$\exp[E_g/KT] = \frac{4.8\times10^{21}(300)^{3/2}}{2.5\times10^{19}}$$

$$'' = 9.9\times10^5$$

ln on both sides.

$$\cancel{\ln(\exp E_g/KT = \ln(9.95\times10^5)}$$

$$E_g/KT = \ln(9.95\times10^5)$$

$$'' = 13.8054.$$

$$E_g = 13.804 \times KT$$

$$E_g = (13.804)\frac{1.38\times10^{-23}(300)}{1.6\times10^{-19}}$$

$$\boxed{E_g = 0.720\,eV.}$$