Semiconductor Electronics : Materials, Devices and Simple Circuits

CHAPTER 14

NCERT FOCUS

ANSWERS

Topic 1

1. **(c) :** For n-type silicon statement (c) is true.

2. **(d) :** For p-type semiconductors statement (d) is true.

3. Conductivity is given by

$$\sigma = e\,(n_e\,\mu_e + n_h\,\mu_h)$$

For intrinsic semiconductor $n_e = n_h = n_i$

Also mobility of holes $(\mu_h) << $ mobility of electrons (μ_e)

So, conductivity $\sigma = en_e\mu_e$

Temperature dependence of intrinsic carrier concentration

$$n_i = n_0 e^{\left(-\frac{E_g}{2k_BT}\right)}$$

So, conductivity

$$\sigma = en_i\mu_e = e\mu_e\, n_0 e^{\left(-\frac{E_g}{2k_BT}\right)}$$

where $e\mu_e n_0 = $ constant σ_0

Hence, $\sigma = \sigma_0 e^{\left(-\frac{E_g}{2k_BT}\right)}$

Conductivity at 600 K, $\sigma_1 = \sigma_0 e^{\left(-\frac{1.2\text{ eV}}{2k_B(600)}\right)}$ ...(i)

Conductivity at 300 K, $\sigma_2 = \sigma_0 e^{\left(-\frac{1.2\text{ eV}}{2k_B(300)}\right)}$ ...(ii)

Dividing (i) and (ii)

$$\frac{\sigma_1}{\sigma_2} = e^{-\left[\frac{0.6\text{ eV}}{600k_B} - \frac{0.6\text{ eV}}{300\,k_B}\right]} = e^{+\frac{0.6}{8.62\times10^5}\left[\frac{1}{600}\right]}$$

or $\frac{\sigma_1}{\sigma_2} = e^{11.6} = 1\times10^5$

So, $\sigma_{(600K)} = 10^5\,\sigma_{(300K)}$

Conductivity increases rapidly with the rise of temperature.

4. **(c) :** The energy band gap is largest for carbon, less for silicon and least for germanium.

So, the correct statement is (c).

$$(E_g)_C > (E_g)_{Si} > (E_g)_{Ge}$$

5. We know that for each atom doped of arsenic, one free electron is received. Similarly, for each atom doped of indium, a vacancy is created.

So, the number of free electrons introduced by pentavalent impurity added

$$n_e = N_{As} = 5\times10^{22}\text{ m}^{-3}$$

The number of holes introduced by trivalent impurity added

$$n_h = N_{In} = 5\times10^{20}\text{ m}^{-3}$$

We know the relation, $n_e n_h = n_i^2$ ...(i)

Now net electrons,

$$n'_e = n_e - n_h = 5\times10^{22} - 5\times10^{20}$$

$$= 4.95\times10^{22}\text{ m}^{-3} \quad \text{...(ii)}$$

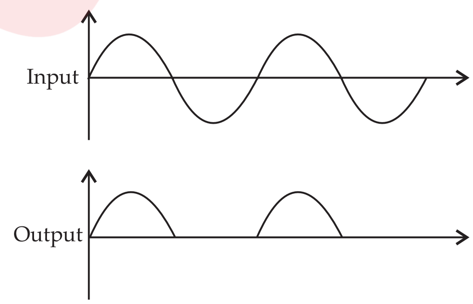
Now using equation (i), net holes

$$n'_h = \frac{n_i^2}{n'_e} = \frac{(1.5\times10^{16})^2}{4.95\times10^{22}} = 4.5\times10^9\text{ m}^{-3}$$

So, $n'_e >> n'_h$, the material is of n-type.

Topic 2

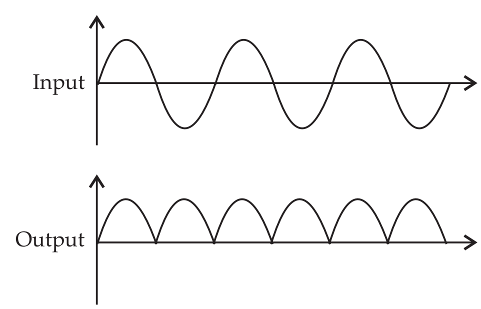
1. In half wave rectification, only one ripple is obtained per cycle in the output.



Output frequency of a half wave rectifier
= input frequency = 50 Hz

In full wave rectification, two ripples are obtained per cycle in the output.

Output frequency = 2 × input frequency
= 2 × 50 = 100 Hz



2. **(c) :** Under forward biasing the movement of majority charge carriers across the junction reduces the width of depletion layer or lowers the potential barrier.

3. **(c) :** In the unbiased p-n junction, holes diffuse from the p-region to n-region because holes concentration in the P-region is high as compared to n-region.

4. The current I through a junction diode is given as

$$I = I_0\left[\exp\left(\frac{eV}{k_BT}\right) - 1\right]$$

where $I_0 = 5 \times 10^{-12}$ A, $T = 300$ K,

$k_B = 8.6 \times 10^{-5}$ eV K^{-1}

$= 8.6 \times 10^{-5} \times 1.6 \times 10^{-19}$ J K^{-1}.

(a) When $V = 0.6$ V

$$\frac{eV}{k_BT} = \frac{1.6\times10^{-19}\times0.6}{8.6\times1.6\times10^{-24}\times300} = \frac{600}{8.6\times3} = 23.26$$

$$\therefore \quad I = I_0\left[\exp\left(\frac{eV}{k_BT}\right) - 1\right]$$

$= 5 \times 10^{-12}$ [exp (23.26) $-$1] A

$= 5 \times 10^{-12}$ [$1.2586 \times 10^{10} - 1$] A

$= 5 \times 10^{-12} \times 1.2586 \times 10^{10}$ A $= 0.06293$ A.

(b) When $V = 0.7$ V,

$$\frac{eV}{k_BT} = \frac{1.6\times10^{-19}\times0.7}{8.6\times1.6\times10^{-24}} = 27.13$$

$$\therefore \quad I = I_0\left[\exp\left(\frac{eV}{k_BT}\right) - 1\right]$$

$= 5 \times 10^{-12}$ [exp (27.13) $-$ 1] A

$= 5 \times 10^{-12} \times [6.07 \times 10^{11} - 1]$ A

$\simeq 5 \times 10^{-12} \times 6.07 \times 10^{11}$ A $= 3.035$ A

Increase in current,

$\Delta I = 3.035 - 0.06293 = 2.972$ A.

(c) For $\Delta V = 0.7 - 0.6 = 0.1$ V, $\Delta I = 2.972$ A

Dynamic resistance,

$$r_d = \frac{\Delta V}{\Delta I} = \frac{0.1}{2.972} = 0.0336\ \Omega.$$

(d) For both the voltages, the current I will be almost equal to I_0, showing almost infinite dynamic resistance in the reverse bias.

$$I \simeq -I_0 = -5\times10^{-12}\text{ A}.$$

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