Semiconductor Electronics : Materials, Devices and Simple Circuits

CHAPTER **14**

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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

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

For intrinsic semiconductor $n_e = n_h = n_i$ Also mobility of holes (μ_h) << mobility of electrons (μ_e) So, conductivity $\sigma = e n_e \mu_e$

Temperature dependence of intrinsic carrier concentration

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

So, conductivity

$$\sigma = e n_i \mu_e = e \mu_e n_0 e \left(-\frac{E_g}{2k_B T} \right)$$

where $e\mu_e n_0 = \text{constant } \sigma_0$

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

Conductivity at 600 K, $\sigma_1 = \sigma_0 e^{\left(-\frac{1.2 \text{ eV}}{2k_B(600)}\right)}$ Conductivity at 300 K, $\sigma_2 = \sigma_0 e^{\left(-\frac{1.2 \text{ eV}}{2k_B(300)}\right)}$

Dividing (i) and (ii)

$$\frac{\sigma_1}{\sigma_2} = e^{-\left[\frac{0.6 \text{ eV}}{600k_B} - \frac{0.6 \text{ eV}}{300 k_B}\right]} = e^{+\frac{0.6}{8.62 \times 10^5} \left[\frac{1}{600}\right]}$$

or $\frac{\sigma_1}{\sigma_2} = e^{11.6} = 1 \times 10^5$

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

 $n_e = N_{As} = 5 \times 10^{22} \text{ m}^{-3}$ The number of holes introduced by trivalent impurity added $n_h = N_{ln} = 5 \times 10^{20} \text{ m}^{-3}$ We know the relation, $n_e n_h = n_i^2$ (i)

Now net electrons, $n_e n_h = 1$

$$n'_e = n_e - n_h = 5 \times 10^{22} - 5 \times 10^{20}$$

= 4.95 × 10²² m⁻³ ...(ii)

Now using equation (i), net holes

$$n'_{h} = \frac{n_{i}^{2}}{n'_{e}} = \frac{(1.5 \times 10^{16})^{2}}{4.95 \times 10^{22}} = 4.5 \times 10^{9} \text{ m}^{-3}$$

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 = $2 \times \text{input frequency}$ = $2 \times 50 = 100 \text{ Hz}$



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.

...(ii)

...(i)

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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 / through a junction diode is given as

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

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

$$\frac{eV}{k_BT} = \frac{1.6 \times 10^{-19} \times 0.6}{8.6 \times 1.6 \times 10^{-24} \times 300} = \frac{600}{8.6 \times 3} = 23.26$$

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

= 5 × 10⁻¹² [exp (23.26) -1] A
= 5 × 10⁻¹² [1.2586 × 10¹⁰ - 1] A
= 5 × 10⁻¹² × 1.2586 × 10¹⁰ A = 0.06293 A

(b) When
$$V = 0.7 V$$
,

$$\frac{eV}{k_B T} = \frac{1.6 \times 10^{-19} \times 0.7}{8.6 \times 1.6 \times 10^{-24}} = 27.13$$

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

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

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

$$\approx 5 \times 10^{-12} \times 6.07 \times 10^{11} A = 3.035 A$$
Increase in current,

 $\Delta I = 3.035 - 0.06293 = 2.972 \text{ A.}$ (c) For $\Delta V = 0.7 - 0.6 = 0.1 \text{ V}$, $\Delta I = 2.972 \text{ A}$ 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.

$$l \simeq -l_0 = -5 \times 10^{-12}$$
 A.

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