Printed Pages : 7 **TEC – 403**

(Following Paper ID and Roll No. to be filled in your Answer Book)

PAPER ID : 3083 Roll No. | | | | | | | | | | |

B. Tech.

(SEM. IV) EXAMINATION, 2008-09

SEMICONDUCTOR MATERIALS & DEVICES

Time : 3 Hours] *[Total Marks : 100*

Note : (1) Attempt **all** the questions.

(2) **All** the questions carry **equal** marks.

1 Attempt any **two** parts of the following :

(a) (i) Describe briefly the lattice structure of silicon. 4

(ii) A Si sample is doped with 10^{17} As atoms/cm^3. What is the equilibrium concentration of holes at 300^oK ? Where is E_F (i.e. the Fermi level) related to E_i (i.e. the intrinsic Fermi level) ? Draw the energy band diagram to show the positions of E_i and E_F. 3+2+1

(b) (i) Derive an expression for the thermal-equilibrium concentration of holes in the valence band of a semiconductor. **5**

(ii) Define the effective density of states function in the valence band. Find the numerical value of the same for a semiconductor in which the effective mass of a hole is $0.56m_0$ where m_0 is the mass of a free electron. **2+3**

(c) (i) Let the donor and acceptor concentrations in a semiconductor be N_a and N_d respectively. Show that the concentration of hole in the semiconductor can be given by **6**

$$p_0 = \frac{N_a - N_d}{2} + \sqrt{\left(\frac{N_a - N_d}{2}\right)^2 + n_i^2}$$

where n_i is the intrinsic carrier concentration.

(ii) Consider a germanium semiconductor at $T = 300^\circ K$. Calculate the thermal equlibrium concentration of electron for $N_a = 10^{14} cm^{-3}$ and $N_d = 0$. Assume $n_i = 2.5 \times 10^{13} cm^{-3}$ for germanium. **4**

2 Attempt any **two** parts of the following :

(a) Describe briefly the direct and indirect recombination process in a semiconductor. 5+5

(b) (i) Define the following terms with suitable examples : 2+2+2

Photoluminescence

Cathodoluminescence

Electroluminescence

(ii) Assume that a photoconductor in the shape of a bar of length L and area A has a constant voltage V applied, and it is illuminated such that g_{op} EHP/cm^3-s are generated uniformly throughout. If $\mu_n >> \mu_p$, we can assume the optically induced change in current ΔI is dominated by the mobility μ_n and lifetime τ_n of electrons. Show that 4

$$\Delta I = \frac{qALg_{op}\tau_n}{\tau_t}$$

for this photoconductor, where τ_t is the transit time of electrons drifting down the length of the bar.

(c) A Si sample is doped uniformly with a donor concentration of 10^{15} cm^{-3} and has $\tau_p = 1\ \mu s$. **4+6**

(i) Determine the photo-generation rate that will produce 2×10^{13} excess pairs per cm^3 in the steady state.

(ii) Calculate the conductivity of the sample and the position of the electron and hole quasi-Fermi levels in the steady state at $300^{o}K$.

3 Attempt any **two** parts of the following :

(a) (i) Show that the built-in potential in a p-n junction can approximately be given by **4**

$$V_0 = \frac{kT}{q} \ln\left(\frac{N_a N_d}{n_i^2}\right)$$

where N_a and N_d are the donor and acceptor concentrations of p- and n-type materials respectively, n_i is the intrinsic carrier concentration and k is the Boltzman constant.

(ii) Consider a silicon p-n junction diode with doping concentrations of $N_a = 10^{15} cm^{-3}$ in p-side and $N_d = 1.5 \times 10^{15} cm^{-3}$. If the diode is reverse-biased by 1.0 V, calculate the total depletion width at the junction. Assume $n_i = 1.5 \times 10^{10} cm^{-3}$. $T = 300^{\circ} K$ and the relative dielectric constant $\varepsilon_r = 11.8$ of the silicon material. **6**

(b) (i) What do you mean by a rectifying contact ? State the condition for which the junction between a metal and n-type semiconductor will work as a rectifying contact. Draw the energy band diagram of a rectifying contract formed between a metal and an n-type semiconductor at equilibrium condition. **2+2+3**

(ii) What are basic characteristic differences between a Schottky diode and a conventional p-n junction diode ? **3**

(c) Write short notes on : 3+4+3

(i) Transition capacitance of p-n junction diode

(ii) Diffusion capacitance of p-n junction diode

(iii) The Varactor diode.

4 Attempt any **two** parts of the following :

(a) (i) Describe briefly the *Ebers-Moll* model of a transistor. 4

(ii) Explain why the turn-on transient of a BJT is faster when the device is driven into over-saturation. 3

(iii) Explain why the current gain in a BJT is decreased when the collector current exceeds a certain value. 3

(b) Discuss briefly the principle of operation of a junction field effect transistor (JFET). Also derive an expression for the I-V characteristic of the device. 4+6

(c) Write short notes on : 3+3+4

(i) Light emitting diode

(ii) p-n junction solar cell

(iii) Double heterostructure laser diode.

5 Attempt any **two** parts of the following :

(a) Describe briefly the principle of operation and characteristic features of a P-N-P-N diode. **10**

(b) Discuss briefly the operation of a TRIAC. **10**

(c) Write short notes on : **5+5**

(i) DIAC

(ii) IGBT.
