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B. Tech

BSCP 1207 (N) / BSCP 2202(O)

Third Semester Examination – 2010

PHYSICS OF SEMICONDUCTOR DEVICES
(New and Old Course)

Full Marks – 70

Time : 3 Hours

(Students are required to give their answer any one Course according to the Syllabus)

(NEW COURSE)

Answer Question No. 1 which is compulsory and any five from the rest.
The figures in the right-hand margin indicate marks.

1. Answer the following questions : 2×10

(a) What do you mean by intrinsic carrier concentration (n_i) ? how is it related with n_o and p_o?

(b) Calculate the built-in potential barrier for silicon pn junction at T = 300 K for $N_a = 5 \times 10^{17} cm^{-3}$, $N_d = 10^{16} cm^{-3}$.

(c) What are the differences between schottky barrier diode and pn junction diode ?

(d) What are the basic differences between JFET and MOSFET ?

(e) What is freeze out condition ?

(f) What is punch-through breakdown in BJT ?

(g) Determine the total number at energy states in Ga As between E_C and E_C+RT at T = 300K.

(h) What do you mean by generator and recombination rates ?

(i) Define inversion layer of charge and when it is formed ?

(j) Write the expressions for carrier diffusion co-efficient in a semiconductor. State its sign and unit.

2. (a) Derive the expression for thermal equilibrium concentration of holes in the valency band using effective density of states function, Fermi energy and other terms. 6

(b) Calculate the thermal equilibrium hole concentration in silicon at T = 400 K. The Fermi energy is 0.27 eV above the valency band energy. $N_v = 1.04 \times 10^{19} cm^{-3}$ at T = 300K. 4

3. (a) Explain the variation of Fermi energy level with doping ******* and temperature using suitable expression and plot. 5

(b) The Fermi energy level for a particular material at T = 300K is 6.25 eV. Find the probability of an energy level at 6.50 eV, being occupied by an electron. 5

4. (a) What do you mean by drift and diffusion densities in semiconductor ? Write the expressions for them. 3

(b) Derive Einstein relation. State the changes occurring in these relations for a n – type and p – type semiconductor. 4

(c) Determine the diffusion coefficient, assuming the mobility of a particular carrier is 1000 $cm^2/v\text{-}s$ at T = 300K. 3

5. (a) Derive expression for the electric field and potential in the space charge region of a uniformity doped pn junction. Derive expression for the space charge width of the junction. 6

(b) A silicon pn junction at T = 300K with zero applied bias has doping concentration of $N_a = 5 \times 10^{15} \text{cm}^{-3}$. Determine the space charge width. 4

6. (a) Derive the ideal diode equation for a pn junction and draw the I-V characteristics curve, under what condition does the reverse bias current density becomes independent of the reverse-bias voltage. 6

(b) A silicon pn junction at T = 300K. Intrinsic carrier concentration $N_i = 1.5 \times 10^{10} \text{cm}^{-3}$. The n type doping concentration is $1 \times 10^{16} \text{cm}^{-3}$, and a forward bias of 0.60V is applied to the pn junction. Calculate the minority carrier hole concentration at the edge of the space charge region. 4

7. (a) What are the different modes of operation of a BJT? In which mode maximum current flows and why? 3

(b) Derive the expression of the excess minority carrier electron concentration in the forward active mode in an n pn bipolar transistor. 4

(c) What is base width modulation ? Explain with suitable diagram. 3

8. (a) What do you mean by CMOS technology ? Sketch the cross section of a CMOS structure. Discuss what is meant by latch-up in a CMOS structure. 4

(b) What is flat band condition in a MOS device ? Write expression for flat band voltage. 2

(c) Calculate the flat-band voltage e for a MOS capacitor with a p-type semiconductor substrate doped to $N_a = 10^{16} cm^{-3}$, a SiO_2 insulator with a thickness of t_{ox} = 500 Å and an n^+ polysilicon gate, assuming that $Q'_{SS} = 10^{11}$ electronic charge/cm^2. 4

(OLD COURSE)

*Answer Question No. **1** which is compulsory and any **five** from the rest.*

The figures in the right-hand margin indicate marks.

1. Answer in brief all the following questions : 2×10

   (a) With the help of suitable diagram, explain the minority carrier distribution in an npn bipolar transistor operating in saturation mode.

   (b) Explain "Early effect" in BJT. How "Early voltage" is determined using the I_C versus V_{CE} plot.

   (c) Interpret the equation $N_o P_o \ n_i^2$. The terms carry their usual meaning.

   (d) What is meant by diffusion resistance of a PN junction diode ? Explain how it is assessed from the V-I Characteristic of the diode.

   (e) Why BJT is a bipolar device, whereas MOSFET is a unipolar device?

   (f) Is $|V_{BE.sat}|$ greater or less than $|V_{CE.sat}|$? Explain.

   (g) What do you mean by a hole and its effective mass in a semiconductor?

   (h) Which of the bipolar transistorconfiguration has the highest input resistance R_i and the lowest output resistance R_o? Justify with proper equations.

   (i) What are the advantages of CMOS logic circuit over other MOS circuits?

   (j) What is meant by inverted mode of operation of a BJT ?

2. (a) Plot minority carrier concentration as a function of distance from the p-n junction under different bias conditions. Indicate the excess concentration in the diagram. What is the law of junction ? 2×3

(b) What do you mean by diode breakdown? Explain the mechanism involved for such behaviour. 4

3. (a) Draw the energy band diagram through the MOS structure in thermal equilibrium after contact. Derive an expression for metal-semiconductor work function difference. 5

(b) Derive the ideal diode equation for a p-n junction diode. Under what condition does the reverse-bias current density becomes independent of the reverse-bias voltage? 5

4. (a) Discuss Ebers-Moll Model and calculate $V_{CE\,(sat)}$ of a BJT at T = 300 K, provided $\alpha_F = 0.99$, $\alpha_R = 0.20$, $I_C = 1\text{mA}$ and $I_B = 50\,\mu\text{A}$. 5

(b) Draw the small signal equivalent circuit of a BJT and determine the approximate frequency at which the small signal current gain decreases to $\frac{1}{\sqrt{2}}$ of its low frequency value, provided if input resistance and capacitance values are $2.5\ \text{K}\Omega$ and $4.0\,f\text{F}$ respectively then calculate the frequency. 5

5. (a) Draw the output characteristic plot for a p-n-p CE transistor configuration. Indicate the active, saturation and cutoff regions in the above plot. Derive the expression for I_C versus I_B for the active region of the transistor operation. 8

(b) An n-type semiconductor is doped at $N_A = 10^{16}\ \text{cm}^{-3}$. Assume 10^{14} electron-hole pairs per cm^3 have been created at t=0. Determine the minority carrier concentration at t=5 ns. 2

6. (a) Give the h-parameter model for the common base transistor configuration. Derive the expression for current gain A_i and input resistance R_i, in terms of h-parameters and the load impedance. 5

(b) Draw the small-signal high-frequency common emitter model of a bipolar junction transistor. What is the physical origin of the capacitors in the model? 5

7. (a) Construct the basic CMOS inverter from the basic MOS devices and explain its operations. Suitably modify the circuit to implement a NAND and a NOR gate. 3+4

(b) What are the significant differences between the construction of an enhancement type and depletion type MOSFET ? 3

8. (a) Derive Einstein's relation between carrier mobility and diffusion coefficient in a semiconductor. 4

(b) Consider a GaAs PN junction with doping densities of $N_A = 10^{18}\,\text{cm}^{-3}$ and $N_D = 10^{15}\,\text{cm}^{-3}$. Calculate the built in potential barrier in this junction. If the acceptor doping concentration changes from $N_A = 10^{18}\,\text{cm}^{-3}$ to $N_A = 10^{16}\,\text{cm}^{-3}$, then find the changes in potential. 6
