APJ Abdul Kalam Technological University Third Semester B.Tech Degree Examination, December 2020

ECT201: Solid State Devices.

PART A

(Answer all questions. Each question carries 3 marks) (p. 1)

1. With suitable examples, distinguish between elemental and compound semiconductors. Give their applications.
2. Draw the energy band diagrams under equilibrium for the following semiconductors: i) intrinsic ii) n type iii) p type.
3. Write down the current equations in a semiconductor.
4. What is the significance of quasi Fermi level? If there is a gradient in quasi Fermi level, what does it indicate?
5. Draw the V-I characteristics of a P-N junction diode & mark the regions of operation. Write down the ideal diode equation.
6. Draw the structure of a PNP transistor. Clearly indicate the current components on the figure.
7. Plot the transfer characteristics of an n-channel MOSFET. Give the current equation.
8. An nMOS transistor has W/L = 4/2, gate oxide thickness $40\ \text{Å}$,. Mobility of electrons $180\ \text{cm}^2/\text{Vsec}$. The threshold voltage is 0.4 V, relative permittivity of gate oxide ϵ_{ox} = 3.9. Calculate the drain current when $V_{gs} = 1.5\ \text{V}, V_{ds} = 1.8\ \text{V}$.
9. What is channel length modulation in MOSFETs? How does it affect the output characteristics of the MOSFET?
10. Explain the principle of operation and advantage of FinFET.

PART B

(Answer any one full question from each module. Each question carries 14 marks) (p. 1)

Module 1

1. (a) Derive the equation for hole concentration in a semiconductor under thermal equilibrium in terms of n_i, E_f and E_i. (8 marks) (p. 1)
   (b) A silicon sample is doped with $2 \times 10^{16}\ \text{cm}^{-3}$ of Boron atoms ($n_i = 1.5 \times 10^{10}\ \text{cm}^{-3}$ for Silicon at 300 K). Determine: i. The equilibrium electron and hole concentrations; ii. Position of Fermi energy level in the band gap; iii. Plot the energy band diagram. (6 marks) (p. 2)
2. (a) Plot and explain the temperature dependence of intrinsic carrier concentration in semiconductors. (4 marks) (p. 2)
   (b) With suitable sketches explain the indirect recombination mechanism via traps. (5 marks) (p. 2)
   (c) An n-type Si sample with $N_d = 10^{15}\ \text{cm}^{-3}$ is steadily illuminated such that $g_{op} = 10^{21}\ \text{EHP/cm}^3\text{s}$. If $\tau_n = \tau_p = 1\ \mu\text{s}$ for this excitation, calculate the separation in the quasi-Fermi levels, ($F_n - F_p$). ($n_i = 1.5 \times 10^{10}\ \text{cm}^{-3}$ for Silicon at 300 K). (5 marks) (p. 2)

Module 2

1. (a) Explain the term mobility with respect to semiconductors. What are the factors on which the mobility depends? Explain the variation of mobility with temperature and doping. (8 marks) (p. 2)
   (b) A potential of 100 mV is applied across a semiconductor bar, and the resulting current is 1 mA. A magnetic field of $10^{-4}\ \text{Wb/cm}^2$ is applied perpendicular to this bar. The Hall voltage measured is -2 mV. The dimensions are width = 0.1mm, length = 5 mm and thickness = $10\ \mu\text{m}$. Find: i. the type of semiconductor; ii. the concentration and mobility of majority carriers. (6 marks) (p. 2)
2. (a) Derive continuity equation for holes. (4 marks) (p. 2)
   (b) Solve the continuity equation under steady state conditions assuming the semiconductor is long and no drift current is present. Plot the solution. (6 marks) (p. 2)
   (c) A p-type semiconductor is injected at one end with minority carrier electrons under steady state conditions.

$N_a = 10^{15}\ \text{cm}^{-3},\ \tau_n = 0.1\ \mu\text{s},\ \mu_n = 700\ \text{cm}^2/\text{Vsec}$.

Calculate the electron diffusion length. (4 marks) (p. 2)

Module 3

1. (a) With the help of energy band diagrams, explain the behaviour of the contact between a metal and an n-type semiconductor. Clearly distinguish between Schottky and ohmic contacts. (10 marks) (p. 2)
   (b) What is base width modulation? How does it affect the input and output characteristics of a BJT? (4 marks) (p. 3)
2. (a) Derive the equation for the built-in potential of a PN junction under thermal equilibrium. (7 marks) (p. 3)

   (b) A PN junction is doped on one side with $10^{18}\ \text{cm}^{-3}$ Boron atoms and the other side with $10^{16}\ \text{cm}^{-3}$ Arsenic atoms at 300 K. $(n_i = 1.5 \times 10^{10}\ \text{cm}^{-3}$ and $\epsilon_r = 11.9)$. Calculate the built-in potential. (3 marks) (p. 3)
   (c) For a PNP transistor:
   $I_{Ep} = 2\ \text{mA},\ I_{En} = 0.01\ \text{mA},\ I_{Cp} = 1.98\ \text{mA}$ and I_{Cn} = 0.001mA. Determine: i. base transport factor; ii. emitter injection efficiency; iii. α and β. (4 marks) (p. 3)

Module 4

1. (a) Draw and explain the C-V Characteristics of an Ideal MOS capacitor. Derive the expression for threshold voltage. (8 marks) (p. 3)
   (b) Draw the energy band diagrams of an ideal MOS capacitor under equilibrium and strong inversion conditions. (6 marks) (p. 3)
2. (a) Draw the structure of n-channel MOSFET. Derive the expression for drain current of a MOSFET in the two regions of operation. What are the assumptions made? (10 marks) (p. 3)
   (b) What is meant by body effect in MOSFET? How does it affect the threshold voltage? (4 marks) (p. 3)

Module 5

ENTRI

1. (a) What is meant by scaling in MOSFETs? Explain the challenges in device scaling. (7 marks) (p. 3)
   (b) Explain the concept of constant voltage scaling and its limitations. (7 marks) (p. 3)
2. (a) What is meant by DIBL in MOSFETs? How does it affect the threshold voltage? (7 marks) (p. 3)
   (b) Explain the concepts of velocity saturation and hot carrier effects in a MOSFET. (7 marks) (p. 3)