ENTRI

APJ Abdul Kalam Technological University Third Semester B.Tech Degree Examination, December 2021

ECT201: Solid State Devices.

PART A

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

1. State and explain law of mass action.
2. Explain the concept of quasi Fermi level.
3. State and explain the terms in Einstein's relation.
4. Distinguish between drift and diffusion mechanisms. Write the expression for the corresponding currents.
5. Explain Early effect and its impact on collector and base currents.
6. Derive the expression for built in potential of a PN junction diode.
7. Draw the energy band diagram of a MOS capacitor at equilibrium, accumulation and strong inversion condition.
8. Explain the transfer characteristics of a MOSFET.
9. Explain Drain induced barrier lowering?
10. Draw and label the structure of a FINFET.

PART B

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

Module 1

1. (a) Define Fermi Dirac distribution function. Explain with relevant figures Fermi Dirac distribution of carriers in intrinsic and extrinsic materials. (10 marks) (p. 1)
   (b) The Fermi level in a Si sample at 300K is located at 0.3eV below the bottom of the conduction band. The effective density of states $N_c = 3.22 \times 10^{19}\ \text{cm}^{-3}$ and N_v = $1.83 \times 10^{19}\ \text{cm}^{-3}$.
   Determine (i) the electron and hole concentration at 300K (ii) the intrinsic carrier concentration at 300K. (4 marks) (p. 1)
2. (a) 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, $(E_{Fn} - E_{Fp})$. (7 marks) (p. 2)

(b) Illustrate the direct and indirect recombination process of excess carriers in semiconductors. (7 marks) (p. 2)

Module 2

1. (a) Explain Hall effect? Derive the expression for determining carrier concentration in a semiconductor bar using Hall effect. (7 marks) (p. 2)
   (b) (i) Show that the minimum conductivity of a semiconductor sample occurs when $n_0 = n_i\sqrt{\frac{\mu_p}{\mu_n}}$.

   (ii) What is the expression for the minimum conductivity σ_{min}? (iii) Calculate σ_{min} for Si at 300 K and compare with the intrinsic conductivity. (7 marks) (p. 2)

2. (a) Derive the expression for drift current density, mobility of carriers and conductivity of a semiconductor. (8 marks) (p. 2)
   (b) A Si sample with $10^{15}/\text{cm}^3$ donors is uniformly optically excited at room temperature such that $10^{19}/\text{cm}^3$ electron-hole pairs are generated per second. Find the separation of the quasi-Fermi levels and the change of conductivity upon shining the light. Electron and hole lifetimes are both $10\ \mu\text{s}.\ D_p = 12\ \text{cm}^2/\text{s}.$. (6 marks) (p. 2)

Module 3

1. (a) Draw the energy band diagram of a metal N type semiconductor with $\phi_m > \phi_s$ under equilibrium condition and on biasing. Is the contact rectifying or ohmic. Justify your answer. (9 marks) (p. 2)
   (b) Assume that a p-n-p transistor is doped such that the emitter doping is 20 times that in the base, the minority carrier mobility in the emitter is one-fourth that in the base, and the base width is one-tenth the minority carrier diffusion length. The carrier lifetimes are equal. Calculate α and β for this transistor. (5 marks) (p. 2)
2. (a) Derive ideal diode equation. (8 marks) (p. 2)

   (b) A Schottky barrier diode is formed from n type Si of a doping 10^{16}cm^{-3} and

area 10^{-3}cm^2. A Si PN junction has the same area and $N_A = 10^{19}\text{cm}^{-3}, N_D = 10^{16}\text{cm}^{-3},$ $\tau_n = \tau_p = 1\mu$ s..

(i) Calculate the Schottky barrier diode current at 0.4V and 300K. (ii) Calculate the value of forward bias to obtain same current for a PN junction. $[R^* = 110$ A/K^2, Electron affinity of Si = 4.15eV, metal work function = 4.9eV, Diffusion constant = $12\text{cm}^2/\text{s}$ (6 marks) (pp. 2-3)

Module 4

1. (a) Draw and explain the CV characteristics of a MOS capacitor. (8 marks) (p. 3)
   (b) For a long channel n-MOSFET with W = 1V (likely error in doc, usually W/L ratio), calculate the V_G required for an $I_{D(sat.)}$ of 0.1 mA and $V_{D(sat.)}$ of 5V Calculate the small-signal output conductance g and the transconductance $g_{m(sat.)}$ at $V_D = 10\text{V}.$. Recalculate the new I_D for $V_G - V_T = 3\text{V}$ and $V_D = 4\text{V}$. (6 marks) (p. 3)
2. (a) Draw and explain the drain characteristics and transfer characteristics of a MOSFET. (8 marks) (p. 3)
   (b) An Al-gate p-channel MOS transistor is made on an n-type Si substrate with N_d = $5 \times 10^{17}\ \text{cm}^{-3}$. The SiO_2 thickness is $100\ \text{Å}$ in the gate region, and the effective interface charge Q_i is 5×10^{10} q C/cm^2 and the work function difference between metal and semiconductor is -0.15V. Find W_{max}, V_{FB}, and V_T of the device. (6 marks) (p. 3)

Module 5

1. (a) Distinguish between constant voltage scaling and constant field scaling. (8 marks) (p. 3)
   (b) Illustrate the operation of FinFET. (6 marks) (p. 3)
2. Explain any four short channel effects in MOSFET. (14 marks) (p. 3)