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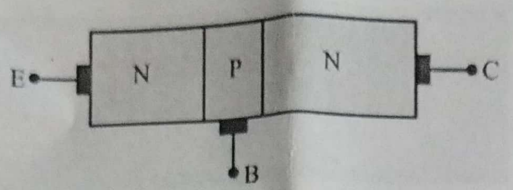
NATIONAL INSTITUTE OF TECHNOLOGY CALICUT
Department of Electronics and Communication Engineering
II Semester B. Tech End Semester Examination
Winter Semester 2024- 2025

Semiconductor Devices (Code: EC1012E)

Time: 3 Hours | Maximum Marks: 40

(i) Answer all the questions
(ii) Draw neat sketches wherever necessary
(iii) Assume any missing data with proper justification

	{Boltzmann constant $k = 1.38\times10^{-23}$ J/K, Electronic Charge $q = 1.6\times10^{-19}$ C, Electron rest mass $m_o = 9.1\times10^{-31}$Kg, Planck's constant $h = 6.63\times10^{-34}$ J-s, E_G for Si = 1.11 eV, $n_i = 1.5 \times 10^{10}$ /cc for Si at 300K, ε_r for Si is 11.8, $\varepsilon_0 = 8.854\times10^{-14}$ F/cm}	
1.	Derive the continuity equation for electrons in a semiconductor starting from the principle of conservation of charge. Clearly state and explain the physical significance of each term in the equation. Also solve it for electron as minority carriers with low level injection, assuming no electric field present and equilibrium concentration does not change with x.	(3)
2.	A rectangular n-type silicon sample has a width of 1 cm, a thickness of 1 mm, and carries a current of 10 mA along its length. A magnetic field of 0.5 T is applied perpendicular to the surface of the sample. The Hall voltage measured across the width is 50 µV. a) Determine the carrier concentration 'n' of the sample. b) Calculate the Hall coefficient (R_H). c) What will happen to the Hall voltage if the type of semiconductor is changed from n-type to p-type?	(2)
3.	An abrupt silicon (Si) p-n junction has $N_A = 10^7$ cm^{-3} on the p-side and $N_D = 10^{15}$ cm^{-3} on the n-side. The area of cross-section of the diode is 10^{-4} cm^2. The relative permittivity of Si is 11.8. Let n_i for Si at 300 K be 1.5×10^{10} cm^{-3}. Determine the following at 300 K: a) Built-in voltage V_{bi} and maximum electric field E_{max} b) Depletion layer width W_o, and its components on the n-side Xn, and p-side Xp c) Charge on one side of depletion layer d) Plot the electric field and charge density to scale.	(4)
4.	A silicon abrupt p-n junction at 300 K has $N_A = 10^{16}$ cm^{-3} on p-side and $N_D = 10^{14}$ cm^{-3} on n-side. Area of cross-section is 10^{-5} cm^2. Calculate the junction capacitance a) At equilibrium b) For a forward-bias voltage of 0.5V c) For reverse-bias voltages of 1V and 10V.	(3)
5.	The following data are given for a silicon abrupt p-n junction at 300 K, where, A=1 cm^2, V_a=0.6V, kT/q = 0.026 V. p-side: $N_A = 10^{18}$ cm^{-3}, $\tau_n = 50$ µs, $D_n = 34$ cm^2/s n-side: $N_D = 10^{16}$ cm^{-3}, $\tau_p = 10$ µs, $D_p = 13$ cm^2/s Calculate I_p ($x_n = 0$); I_n ($x_p = 0$) and the total diode current.	(3)
6	A metal–semiconductor contact is formed between tungsten and n-type silicon with $N_D = 10^{15}$ cm^{-3} is made at 300 K. Calculate the contact potential, equilibrium depletion layer width, maximum electric field at equilibrium. Given $\phi_m = 4.5$V, $\Psi_S = 3.84$ V, $N_c = 2.8 \times 10^{19}$ cm^{-3}, $\epsilon_r = 11.8$.	(2)
7.	A germanium p-n junction diode has $N_D = 10^{16}$ cm^{-3} on the n-side and $N_A = 10^{19}$ cm^{-3} on the p side. Calculate the forward voltage at which injected hole concentration at the edge of the depletion region on the n-side becomes equal to the majority carrier concentration. Assume, T = 300 K, Dp	(3)

	$= 40\ cm^2/s$, $\tau_p = 1$ ps. Calculate the current density at this voltage and compare with thermal equilibrium diffusion current density ($n_i = 2.5 \times 10^{13}\ cm^{-3}$).	
8.	Draw the energy band diagram of the device shown below for a) Equilibrium b) EB junction is forward biased and CB junction is reverse biased  	(3)
9.	A MOS capacitor is constructed using p^+ polysilicon as the gate material, a 10 nm thick SiO_2 layer, and an n-type silicon semiconductor with doping concentration $N_d = 10^{15}\ cm^{-3}$. Assume temperature T=300K and ϕ_{ms}=0.3216V Calculate the following: a) Cox (oxide capacitance per unit area) b) ϕ_{fn} (Fermi potential: E_i−E_f, in the bulk) c) ϕ_{sT} (Surface potential at threshold condition) d) x_{dT} (Maximum depletion width) e) V_{FB} (Flat-band voltage), given that the total oxide charge density $Q'_{SS}=10^{-7}\ C/cm^2$ f) V_T (Threshold voltage) g) Draw the band diagram for $V_G = V_{threshold}$	(4)
10.	Draw the energy band diagrams of a MOS capacitor with a p-type silicon substrate under the following biasing conditions: a) Accumulation b) Depletion c) Inversion. Clearly indicate the positions of the conduction band E_c, valence band E_v, intrinsic level E_i, Fermi level E_F, and the vacuum level. Also, explain briefly the physical mechanism in each region and the effect of gate voltage polarity on the band bending.	(3)
11.	Draw and the C–V characteristic curve of a MOS capacitor with a p-type silicon substrate for both high-frequency and low-frequency measurements. Clearly indicate the accumulation, depletion, and inversion regions on the curve. Why the capacitance behaves differently in the inversion region for high-frequency and low-frequency cases.	(2)
12.	Consider a MOS capacitor constructed using p-type silicon. It has an oxide thickness of 100 nm, a fixed positive oxide charge of $10^{-8} C/cm^2$ at the oxide-silicon interface, and a metal work function of 4.6eV. Assume that the relative permittivity of the oxide is 4 and the absolute permittivity of free space is 8.85×10^{-14} F/cm. If the flat band voltage is 0 V, the work function of the p-type silicon (in eV, rounded off to two decimal places) is ______	(2)
13.	Derive an expression for the drain current of an N-channel MOSFET in the triode and saturation regions.	(3)
14.	Consider a MOSFET with $L_{min} = 0.8\ \mu m$, t_{ox}= 15 nm, μ_n= 550 $cm^3/V.s$, and $V_{th} = 0.7$ V. a) Calculate the oxide capacitance per unit area C_{ox} and the process trans-conductance parameter K'. b) For an NMOS transistor with $W/L = 16\ \mu m/0.8\ \mu m$, compute the values of overdrive voltage V_{OV}, gate-source voltage V_{GS}, and minimum drain-source voltage V_{Dsmin} required to operate the transistor in the saturation region with a DC current I_D= 100 μA. c) For the same device in part (b), determine the values of V_{OV} and V_{GS} required to cause the device to operate as a 1000 Ω resistor for very small V_{DS}	(3)

-- All the best--