Final Assessment Test – June 2023

VIT

Vellore Institute of Technology

Course: BECE201L - Electronic Materials and Devices

Class NBR(s): 4646

Slot: A2+TA2

Time: Three Hours

Max. Marks: 100

KEEPING MOBILE PHONE/SMART WATCH, EVEN IN "OFF" POSITION IS TREATED AS EXAM MALPRACTICE

General Instructions: Silicon: $m^*=0.26\ m_0$ $N_C = 2.8\times10^{19}\ cm^{-3}$, $N_V = 1.04\times10^{19}\ cm^{-3}$, $n_i = 1.5\times10^{10}\ cm^{-3}$, $E_g = 1.1$ eV, Relative permittivity $\varepsilon_r=11.8$, $\mu_n= 1350\ cm^2/V\text{-}s$, $\mu_p = 480\ cm^2/V\text{-}s$. Other Constants: kT=0.026 eV at 300K, Boltzmann's constant $k= 8.66\times10^{-5}$ eV/K, $\varepsilon_0=8.854\times10^{-14}$ F/cm, $q=1.6\times10^{10}$ C, $m_0=9.1\times10^{-31}$ kg.

Answer ALL Questions

(10 X 10 = 100 Marks)

1. a) Determine the drift mobility and the mean scattering time of conduction electrons in copper at 300 K, given that the conductivity of copper is $5.9\times10^5\ \Omega^{-1}\ cm^{-1}$. The density of copper is $8.96\ g\ cm^{-3}$ and its atomic mass is $63.5\ g\ mol^{-1}$. If the mean speed of the conduction electrons in Cu is roughly $1.6\times10^6\ m\ s^{-1}$, what is the mean free path between collisions? [5]

   b) A brass disk of electrical resistivity 50 nΩ m conducts heat from a heat source to a heat sink at a rate of 10 W. If its diameter is 20 mm and its thickness is 30 mm, what is the temperature drop across the disk, neglecting the heat losses from the surface? [5]

2. a) Calculate the density of states per unit volume with energies between 0 and 1 ev. [5]

   b) Calculate the energy in terms of K_T and E_F at which the difference between the Boltzmann approximation and the Fermi-Dirac function is 5% of the Fermi-Dirac function. [5]

3. An *n*-type Si wafer has been doped uniformly with 10^{16} antimony (Sb) atoms cm^{-3}. Calculate the position of the Fermi energy with respect to the Fermi energy E_{Fi} in intrinsic Si. The above *n*-type Si sample is further doped with 2×10^{17} boron atoms cm^{-3}. Calculate the position of the Fermi energy with respect to the Fermi energy E_{Fi} in intrinsic Si. Draw the energy band diagram and label the calculated Fermi level positions. (Assume that $T = 300$ K, and $kT = 0.0259$ eV). [10]

4. a) Given that the density of states related effective masses of electrons and holes in Si are approximately $1.08m_e$ and $0.60m_e$, respectively, and the electron and hole drift mobilities at room temperature are 1400 and 450 $cm^2\ V^{-1}\ s^{-1}$, respectively, calculate the intrinsic concentration and intrinsic resistivity of Si. [6]

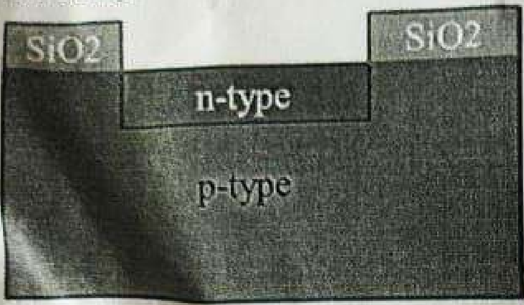
   b) Assume that, in an n-type semiconductor at T = 300 K, the electron concentration varies linearly from 1×10^{18} to $7\times10^{17}\ cm^{-3}$ over a distance of 0.1 cm. Calculate the diffusion current density if the electron diffusion coefficient is $D_n = 22.5\ cm^2/s$. [4]

5. A PN-Junction is formed using a p-type silicon substrate as shown below. The p-type substrate is doped with an impurity concentration of $10^{14} cm^{-3}$ and the n-well is created by a uniform doping of $10^{17}\ cm^{-3}$ for a depth of 100 nm using an ion-implantation technique.

   a) Calculate the relative position of a Fermi-level from the respective band edges and draw the energy band diagrams of P-type semiconductor and N-type semiconductor regions. [4]

b) Draw the energy band diagram of the PN-Junction and label Fermi-level position under thermal equilibrium condition [3]

c) Compute the built-in potential of the PN-junction and label it on the energy band diagram. Assume that $N_c = 2.81 \times 10^{19} cm^{-3}$, $N_V = 1.83 \times 10^{19} cm^{-3}$. [3]



6. Consider an n-type Si sample doped with 10^{16} donors cm^{-3}. The length of the sample, L, is 100 μm; the cross-sectional area, A, of the sample is 10 $\mu m \times 10\ \mu m$. The two ends of the sample are labelled as B and C. The electron affinity (χ) of Si is 4.01 eV and the work functions, Φ, of four potential metals for contacts at B and C are listed in Table. The effective density of states at the conduction edges is $2.8 \times 10^{25}\ m^{-3}$. Assume temperature $T = 300$ K.

Table: Work functions in eV

Cs	Li	Al	Au
1.8	2.5	4.25	5.1

a) Ideally, which metals will result in a Schottky contact? [4]

b) Ideally, which metals will result in an Ohmic contact? [2]

c) Sketch the I-V characteristics when both B and C are ohmic contacts. What is the relationship between I and V? [4]

7. For a silicon one-sided abrupt junction with $N_A = 1.5 \times 10^{20}\ cm^{-3}$ and $N_D = 2 \times 10^{15}\ cm^{-3}$, calculate the depletion width and the maximum or peak electric field (E_{MAX} or E_{PEAK}) at the junction. [10]

8. a) Determine the collector and emitter currents of a NPN-Bipolar Junction Transistor (BJT). Assume a common-emitter current gain of $\beta = 200$ and a base current of $I_B = 40$ μA. Also, assume that the transistor is biased in the forward-active mode. Also draw its energy band diagram. [5]

b) Describe the BJT in the common emitter configuration through a clear diagram. Draw the schematic input and output characteristics. Explain different regions in the output characteristics. [5]

9. For an ideal Al-SiO_2-P-Si MOS capacitor with 5nm SiO_2 dielectric thickness, $N_A = 10^{17} cm^{-3}$ substrate doping, find the applied voltage and the electric field at the interface required to make the silicon surface intrinsic. Also, draw the equilibrium energy band diagram of the above MOS capacitor. [10]

10. a) Write short notes on Ferroelectric materials properties with suitable diagrams and also list out various applications. [5]

b) With neat schematic diagrams, explain various polarization mechanisms in dielectrics. [5]

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