Final Assessment Test – June 2023

Course: BECE201L - Electronic Materials and Devices

Class NBR(s): 4640 Slot: A

Time: Three Hours Max. [illegible]

KEEPING MOBILE PHONE/SMART WATCH, EVEN IN 'OFF' POSITION IS TREATED AS EXAM MAL[illegible]

Answer ALL Questions

(10 X 10 = 100 Marks)

1. a) The Hall coefficient and conductivity of copper at 300 K have been measured to be $-0.54 \times 10^{-10}\ m^3\ A^{-1}\ s^{-1}$ and $5.9 \times 10^7\ \Omega^{-1}\ m^{-1}$, respectively. Calculate the drift mobility of electrons in copper. [4]

   b) A brass disk, with electrical resistivity 40 nΩ-m at a room temperature, conducts heat from a heat source to a heat sink at a rate of 20 W. If its diameter is 30 mm and its thickness is 40 mm, what is the temperature drop across the disk, neglecting the heat losses from the surface? Assume Wiedemann-Franz-Lorenz coefficient is $2.44 \times 10^{-8}\ W\Omega K^{-2}$. Given that $\sigma = 1/\rho = 1/(40\ n\Omega\text{-m})$, $T = 300$ K, $Q' = dQ/dt = 20$ W, $D = 30$ mm, $L = 40$ mm, and $C_{WFL} = 2.44 \times 10^{-8}\ W\Omega K^{-2}$. (Q is the heat) [6]

2. a) Calculate the probability that a quantum state in conduction band at $E = E_C + 2kT$ is occupied by an electron.

   b) Calculate the thermal equilibrium electron concentration in silicon.

   c) What is the type of material? Draw a neat band diagram (Assume Fermi Energy is 0.15eV below conduction band, $N_c = 2.5 \times 10^{20}\ cm^{-3}$ and $T = 300K$).

3. A new semiconductor has $N_c = 5 \times 10^{19}\ cm^{-3}$, $N_v = 8 \times 10^{18}\ cm^{-3}$ and $E_g = 1.8$ eV. If it is doped with $5 \times 10^{17}\ cm^{-3}$ acceptors, calculate the electron, hole and the intrinsic carrier concentration at 327 °C. Show Fermi level on suitable band diagram.

4. a) A GaAs semiconductor resistor is doped with acceptor impurities at a concentration of $N_a = 10^{17}\ cm^{-3}$. The cross-sectional area is 85 μm². The current in the resistor is to be I = 20 mA with 10 V applied. Determine the required length of the device. [4]

   b) For a silicon crystal, the hole concentration is given by $p = 10^{16} \exp(-x/L_p)$ for $x \geq 0$ and the electron concentration is given by $n = 5 \times 10^{15} \exp(x/L_n)$ for $x \leq 0$. The values of L_p and L_n are 5×10^{-4} cm and 10^{-3} cm respectively. Find the total current density which is the sum of hole and electron diffusion current density at $x = 0$. [6]

5. An ideal one-sided silicon n+p junction has uniform doping on both sides of the abrupt junction. The doping relation is $N_d = 50\ N_a$. The built-in potential barrier is 0.752 V. A reverse-bias voltage of 10 V is applied. T = 300 K. Determine

   (a) N_a, N_d (b) x_p, for $V_r = 10$ V and (c) C_{dep} for $V_r = 10$ V.

6. Sketch the energy band diagrams, before and after the contact, of a metal-n-type semiconductor contact with $\phi_m < \phi_{sc}$. How would the band diagram change before and after the contact if $\phi_m > \phi_{sc}$? Explain whether the contacts created in both the cases is Schottky or Ohmic.

7. a) A Silicon PNP BJT with Emitter doping, $N_E = 5 \times 10^{18}$ cm^{-3}, base doping $N_B = 10^{17}$ cm^{-3}, collector doping $N_C = 10^{15}$ cm^{-3} and base width $W_B = 3$ μm is at equilibrium at room temperature. [6]

(i) Sketch the energy band diagram for the device, properly positioning the Fermi level in the three regions.

(ii) Bias voltages of $V_{EB} = 0.6$ V and $V_{CB} = -2$ V are now applied to the BJT. Sketch the energy band diagram for the device, properly positioning the Fermi level in the three regions.

b) Draw the schematic input and output characteristics of an N^+PN bipolar junction transistor in common emitter configuration with appropriate labelling and appropriately specified physical parameters. [4]

8. Consider a MOS capacitor fabricated on a P-type silicon with a doping of $N_a = 5 \times 10^{16} cm^{-3}$ with an oxide thickness of 2 nm and an N^+ poly-gate.

(a) What is the flat-band voltage, V_{fb}, of this capacitor?

(b) Calculate the maximum depletion region width, W_{dmax}.

(c) Find the threshold voltage, V_t, of this device.

9. For a MOSFET with $V_T = 1$V and W = 50 μm, L = 2 μm, calculate the drain current at $V_G = 5$ V, $V_D = 0.1$ V. Repeat for $V_G = 3$ V, $V_D = 5$ V. Assume an electron channel mobility = 200 cm^2/V-s, and the substrate is connected to the source. Assume the oxide thickness to be 10 nm. Draw a neat energy band diagram of the MOS capacitor when this MOSFET is turned ON.

10. (a) What are the key differences between dielectrics and insulators? Explain polarization with suitable diagrams.

(b) With the help of suitable sketches and equations describe ferroelectricity and ferromagnetism.

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