THE OPEN UNIVERSITY OF SRI LANKA
DIPLOMA IN TECHNOLOGY (level 03)
ECD 1209
PHYSICAL ELECTRONICS
FINAL EXAMINATION 2005

035

DATE : 30th April 2006 **TIME : 9.30 – 12.30 hours**

Answer any **FIVE** questions.

1. A pure Si specimen .of cylindrical shape has a cross sectional area of 10^{-4} cm^2. The charge carrier concentration is 10^{24} m^{-3}. A current of 1.5A flows along the cylindrical specimen at a temperature of 27^0 C. Find the thermal velocity and the drift velocity of carriers in this specimen.

   Is given data adequate to find the mean free path and mean free time of electrons in this specimen? If not, state what additional information is required.

2. A resistor in an integrated circuit made of Si has dimensions 2 μm x 1 μm x 40 μm. The doping level is uniformly 10^{30} atoms per m^3 of boron(B). Find the resistance at a temperature of 27^0 C.

   Find the number of electrons in the resistor and show that the current they carry is negligible. Assume for Si at 300^0 K $n_i = p_i = 1.4 \times 10^{16}$ m^{-3}, $\mu_e = 0.135$ m^2/Vs and $\mu_h = 0.048$ m^2/Vs.

3. Find the diffusion current density if the electron number density varies linearly from 10^{24} m^{-3} to 10^{12} m^{-3} over a distance of 10 μm and the electron diffusion coefficient is 3.5×10^{-3} m^2 s^{-1}.

   Find the magnitude and the sign of the electric field, which will produce an equal drift current to the diffusion current calculated above, if the electron mobility is 0.14 m^2/Vs. Use the electron number density at the mid point of the linear range.

4.

(a) What is the effective charge and mass of a hole?

(b) Give the relationship between the mass and the wavelength of a particle.

(c) Calculate the number of electrons passing a point in the conductor per second, if the current in the conductor is 0.5 A.

(d) Obtain the uncertainty in the velocity of an electron confined within a volume of 10^{-15} m^3.

5.

(a) Calculate the approximate intrinsic electron concentration in diamond at a temperature of 150^0C. Assume that the energy gap is 5.3 eV and also that N_C and N_V are independent of temperature and are equal to 2×10^{24} m^{-3}.

(b) When electrons and holes recombine in GaAs, the energy released is emitted as photons. If the energy gap is 1.43 eV, what is maximum emitted wavelength?

6. A diode made in Ge have doping concentrations $N_D = 10^{20}$ m^{-3} and $N_A = 10^{24}$ m^{-3} at 27^0 C. Find

(a) the built-in voltage at the junction
(b) the depletion layer width at zero bias

If the given data is not adequate to perform above calculations, state what additional information is required in each case. Explain in point form the procedure that should be followed in order to find what is asked under (a) and (b).

7. The saturation drain current for a n-MOSFET is 5 mA at $V_{GS} = 12$ V and 10 mA at $V_{GS} = 16$ V. Estimate the threshold voltage and the value of C_{ox}.W/L.

8. A pnp bipolar silicon transistor has a base doping of 10^{24} m^{-3}, an effective base width of 1.5 μm and a junction area of 10^{-4} cm^2. What emitter-base voltage will sustain a collector-current of 5 mA when the collector junction is reversed biased? Make a sketch of the hole concentration in the base region under these conditions.

For Si assume μ_e=0.135 m^2/Vs and μ_h=0.048 m^2/Vs.

$e = 1.6 \times 10^{-19}$ C

$m_e = 9.108 \times 10^{-31}$ kg

$h = 6.625 \times 10^{-34}$ Js

$c = 3 \times 10^{8}$ ms^{-2}

$P_n = nh/2\pi r \quad \lambda = h/p \quad \Delta x.\Delta p \geq h \quad \Delta E.\Delta t \geq h$

$\sqrt{\overline{c^2}} = \sqrt{(3KT/m_e)} \quad J = -ne\overline{v}$

$R_H = -(1/ne) = (1/pe)$

$p_n = n_i^2/N_D \quad n_p = n_i^2/N_A$

$D_e/\mu_e = KT/e \quad E = hc/\lambda$

$J_e = ne\mu_e E + eD_e\,(dn/dx)$

$n = N_c \exp -(E_c - E_F)/KT$

$n_i = \sqrt{N_c N_v} \exp\text{-}(Eg/2KT)$

$V_0 - V = (D_e/\mu_e).\ \ln(n_n/n_p)$

$I_s = A\,[\,(D_e e n_p/L_p) + (D_h e p_n/L_n)]$

$W_{n0}^2 = (2\varepsilon V_0/e).\ [N_A/(N_A N_D + N_D^2)]$

$k = 1.38 \times 10^{-23}$ J/k

$1\ eV = 1.6 \times 10^{-19}$ J

$\varepsilon o = 8.854 \times 10^{-12} F/m$

$I = N_- n_- e + N_+ n_+ e$

$R = \rho.l/A \quad \rho = 1/\sigma \quad J = \sigma E$

$\overline{v} = e\tau E/m_e$

$\mu_e = e\tau/m_e \quad \mu_h = e\tau/m_h$

$\lambda = \tau\sqrt{\overline{c^2}} \quad D = (\lambda/3).\sqrt{\overline{c^2}}$

$\sigma = \mu_e n e = \mu_h p e$

$J_h = pe\mu_h E - eD_h\,(dp/dx)$

$p = N_v \exp -(E_F - E_c)/KT$

$V_0 = (KT/e).\ \ln(N_D N_A/n_i^2)$

$I = I_s\,[\,\exp(eV/KT) - 1]$

$W_n^2 = W_{n0}^2\,(1 - V/V_0) \quad W = W_n + W_p$

$W_{p0}^2 = (2\varepsilon V_0/e).\ [N_D/(N_A N_D + N_A^2)]$