EDC TEST-I Solutions

on Basics, Hall Effect, Fermi Level, PN junction

(1) The diode V-I Equation is

$$i_d = i_o\left(e^{\frac{V_d}{\eta V_T}} - 1\right) \quad \text{—(1)}$$

given that it is approximated as

$$i_d \overset{\sim}{=} i_o\, e^{V_D/V_T} \quad \text{—(2)}$$

Lets ~~assume~~ put $\eta = 1$ in the Eq (1) Since it is Ge diode

So the diffn of i_d in (1) and (2) Should be $< 1\%$

$$\frac{(2) - (1)}{(1)} < 1\%$$

$$= \frac{i_o}{i_o\left(e^{V_D/V_T} - 1\right)} < \frac{1}{100}$$

$$e^{V_D/V_T} - 1 > 100$$

$$e^{V_D/V_T} > 101$$

$$\frac{V_D}{V_T} > \ln(101)$$

$$V_D > V_T \ln(101)$$

$$V_D > \frac{T}{11600} \ln(101)$$

$$= V_D > \frac{(273+25)}{11600} \ln(101)$$

$$V_D > 0.1186 \text{ volts}$$

(2) $T_1 = 25^\circ c \quad T_2 = 50^\circ c$

$$I_{T_2} = I_{T_1}\, 2^{\frac{T_2 - T_1}{10}} \Rightarrow I_{T_2} = I_{T_1}\, 2^{2.5}$$

$$\frac{I_{T_2}}{I_{T_1}} = 5.6569 \Rightarrow \frac{I_{T_2}}{I_{T_1}} - 1 = 4.6569$$

$$\Rightarrow \left(\frac{I_{T_2} - I_{T_1}}{I_{T_1}}\right) \times 100 \cong 465.7\%$$

(3) $E_g = 1.107\ eV$

from fermi-dirac statistics

$$f(E) = \frac{1}{1 + e^{\left(\frac{E-E_f}{kT}\right)}} \quad \text{—} (1)$$

The probability of Electron being in the Conduction band is

Substitute $E = E_c$ and $E_f = \frac{E_c + E_v}{2}$ in (1)

$$F(E) = \frac{1}{1 + e^{\left(\frac{E_c - E_v}{2kT}\right)}} = \frac{1}{1 + e^{\frac{E_g}{2kT}}}$$

$E_g = 1.107\ eV$

$k = 8.62 \times 10^{-5}\ eV/°K$

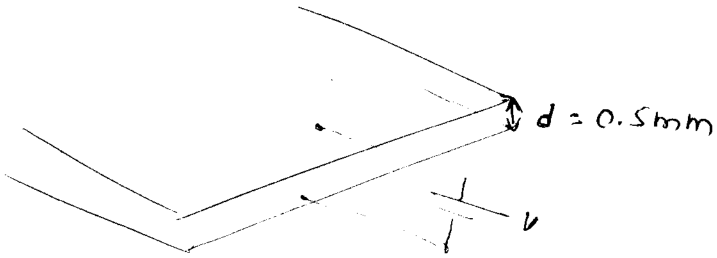
$T = 298\ °K$

$F(E) \approx 4.4 \times 10^{-10}$

(4) Thickness = 0.5 mm

applied potential across thickness is $V = 100\ mV$

$u_n = 0.2\ m^2/V\text{-}s$



$V = Ed$

$100\ mV = E\ 0.5 \times 10^{-3}\ m$

$E = \frac{100}{0.5} = 200$

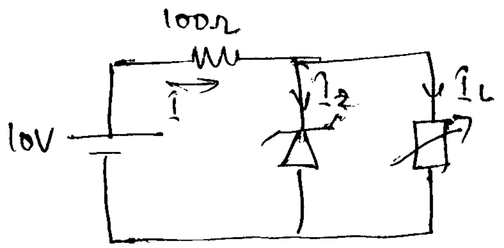
$v_d = u_n E \Rightarrow v_d$ is drift velocity

$v_d = 0.2 \times 200 = 40\ m/sec$

Distance = Velocity x time

$$\text{Time} = \frac{\text{Distance}}{\text{Velocity}} = \frac{0.5\ mm}{40} = 12.5\ \mu sec$$

(5)



$I = I_Z + I_L$

$I_L = I - I_Z$

$= \frac{10 - V_Z}{100} - I_Z$

$I_{Lmax} = \frac{10-5}{100} - I_{Zmin} = 50mA - 10mA = 40mA$

There is typo error, it should be maximum power rating of diode

$P_Z = V_Z I_Z$

$P_{Zmax} = V_Z I_{Zmax} = V_Z (50mA)$ [If total current pass thru diode only]

$= 5(50mA) = 0.25W$

(6) It can not be average of fermilevels of two sides

(7) Junction capacitance $C_j \propto \sqrt{V_F}$ in forward biase

$C_j \propto \frac{1}{\sqrt{V_R}}$ in Reverse bias

Problem should mention forward voltage or reverse voltage

assuming reverse voltage C_j decrease by factor 2

(8) Hall Effect is useful in finding mobility of carriers and concentration and conductivity.

So (a) & (b) are correct.

$I_D = I_s\left(e^{\frac{0.3}{2\times25\times10^{-3}}} - 1\right)$

(9) $R_D = \frac{\eta V_T}{I_D + I_S} = \frac{2 \times 25 \times 10^{-3}}{I_D + 10 \times 10^{-6}}$

$\simeq 15.625\Omega$

(10)

$$\sigma_p = \frac{1}{2\ \Omega/cm}$$

$$\sigma_n = \frac{1}{1\ \Omega/cm}$$

$$\sigma_p \cong pq\mu_p \cong N_A q\mu_p = \frac{1}{2} \Rightarrow N_A = \frac{1}{2q\mu_p}$$

$$\sigma_n \cong N_D q\mu_n = 1 \quad N_D = \frac{1}{q\mu_n}$$

$$W_{dep} = \sqrt{\frac{2\varepsilon}{q}\left(\frac{1}{N_A}+\frac{1}{N_D}\right)V_0}$$

$$= \sqrt{\frac{2\varepsilon}{q}\left(2q\mu_p + q\mu_n\right)V_0}$$

$$= \sqrt{2\varepsilon\,(2\mu_p+\mu_n)\,V_0}$$

$$W_{dep} = \sqrt{5000\ \varepsilon\ V_0}$$

$$V_0 = V_T \ln\left(\frac{N_A N_D}{n_i^2}\right)$$

$$= 26\times10^{-3}\ln\left(\frac{1}{(2q\mu_p)(q\mu_n)}\cdot\frac{1}{n_i^2}\right)$$

$$= 26\times10^{-3}\ln\left(\frac{1}{2\times(1.6\times10^{-19})^2\times500\times1500}\cdot\frac{1}{(1.5\times10^{10})^2}\right)$$

$$V_0 = 0.6623$$

$$\varepsilon = \varepsilon_0\varepsilon_r = 12\varepsilon_0 = 12\times8.854\times10^{-12}\ F/m = 12\times8.854\times10^{-14}\ F/cm$$

$$W_{dep} = \sqrt{5000\times12\times8.854\times0.6623}\times10^{-7}$$

$$= 593.1\times10^{-7}\ cm$$

$$= 59.3\times10^{-8}\ cm$$

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(11) $T\uparrow \quad \rho\downarrow$

$\rho = \frac{1}{\sigma}$

$\sigma = nq\mu_n + pq\mu_p$

as Temp. increases μ_n and μ_p decreases $\left(\mu \propto \frac{1}{T^m}\right)$

but n & p increases

(12) $C_j = \frac{C_{j0}}{\left(1+\frac{V_R}{V_0}\right)^{1/2}}$ for Equal doping on both p and n

$C_j \propto V_R^{-1/2}$

(13) $\tau_n = 78\ \mu sec$

$\mu_n = 0.36\ m^2/v\text{-}sec$

$L_n = \sqrt{D_n \tau_n}$

$\frac{D_n}{\mu_n} = V_T \Rightarrow D_n = 26\times10^{-3}\mu_n$

$L_n = \sqrt{26\times10^{-3}\times0.36\times78\times10^{-6}} = 0.86\ mm$

(14) $N_D = 10^{14}$ atoms/cm^3 $\quad N_A = 8\times10^{13}$ atoms/cm^3

$E = 2.5\ V/cm$ $\quad \mu_p = 1800\ cm^2/v\text{-}s$ $\quad \mu_n = 3800\ cm^2/v\text{-}s$

$\sigma_i = n_i q(\mu_n + \mu_p)$

$\frac{1}{70} = n_i q(1800+3800)$

$n_i = 1.59\times10^{13}/cm^3$

from Charge neutrality

$N_D + p = N_A + n$ —①

$\Rightarrow$ $p - n = N_A - N_D$ (or) $n - p = N_D - N_A$

from mass action law $np = n_i^2$ —②

$n - p = 10^{14} - 8\times10^{13}$

$n - p = 2\times10^{13}$

from ② $p = \frac{n_i^2}{n}$

so $n - \frac{n_i^2}{n} = 2\times10^{13}$

$n^2 - 2\times10^{13}n - n_i^2 = 0$

a quadratic Equation the roots are

$$= \frac{2\times10^{13} \pm \sqrt{(2\times10^{13})^2 + 4n_i^2}}{2}$$

$$= \frac{2\times10^{13} \pm \sqrt{4\times10^{26} + 4\times(1.59)^2\times10^{26}}}{2}$$

$$= \frac{10^{13}}{2}\left[2 \pm \sqrt{14.1124}\right]$$

Concentration cannot be negative so

$n = 2.8783\times10^{13}$

from(2) $p = \frac{(1.59\times10^{13})^2}{n} = 0.8783\times10^{13}$

$J = \sigma E = (n\mu_n + p\mu_p)qE = 50.11\ mA/cm^2$

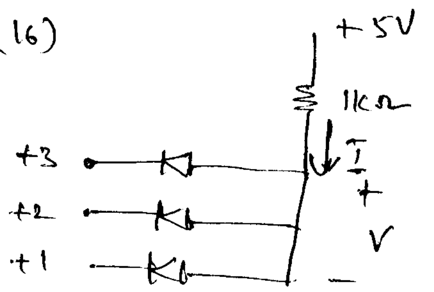
(15) $J_p = -\frac{dp(x)}{dx} D_p q$

$$= -\left[\frac{P(L) - P(0)}{L}\right] \times 12 \times 1.6 \times 10^{-19}$$

$$= -\left[\frac{0 - 10^{12}}{10^{-3}}\right] \times 12 \times 1.6 \times 10^{-19}$$

$$J_p = 19.2 \times 10^{-4} \ A/cm^2$$

(16)



$I = \frac{5-1}{1k} = 4\,mA$

$V = 1V$

(17) from the charge neutrality equation $x_p N_A A q = x_n N_D A q$

$\frac{x_p}{x_n} = \frac{N_D}{N_A}$ so depletion region is more deeper in to lightly doped material

(18)

$$V_z \propto \frac{1}{\text{doping}}$$

(19)

$$F(E) = \frac{1}{1 + e^{\frac{E - E_F}{kT}}} \quad \text{If } E = E_F$$

$$F(E) = 1/2$$

(20)

$$\rho = \frac{1}{nq\mu_n + pq\mu_p}$$

~~Since~~ given that n, p, q are same for Ge, Si. Since mobilities are low for Silicon, Resistivity is high.