

Solutions HW #7

ECE 606

Fall 2012

Q1
$$I_0 = Aq n_i^2 \left[\frac{D_p}{N_D w_n} + \frac{D_n}{N_A w_p} \right]$$

In a p⁺n diode. $N_A \gg N_D$

$$\therefore I_0 = Aq n_i^2 \left[\frac{D_p}{N_D w_n} \right] \text{ (approx.)} \quad \text{--- (1)}$$

Also $D_p = \mu_p kT/q$

At 300 K, $D_p = 0.026 \times 350 \text{ cm}^2/\text{s} = 9.1 \text{ cm}^2/\text{s}$.

$n_i = 1.5 \times 10^{10} \text{ cm}^{-3}$

$$\therefore I_0 = 1.638 \times 10^{-14} \text{ A (using eq 1)}$$

At 400K $\Rightarrow D_p = 12.25 \text{ cm}^2/\text{s}$, $n_i = 5.185 \times 10^{12} \text{ cm}^{-3}$

$$\left[n_i \propto T^{3/2} \exp(-E_g/2kT) \right]$$

$$\therefore I_0 = 2.635 \times 10^{-9} \text{ A}$$

Saturation current increases by five orders when the rise in temperature is 100 C.

Q2
6.10

(a) **Reverse biased** — there is a deficit of minority carrier in the quasineutral region immediately adjacent to the depletion region.

(b) Low-level injection DOES prevail. As required for low-level injection

$$|\Delta n_p|_{\max} \cong n_{p0} \ll p_p \quad \dots \text{ for } x \leq -x_p$$

$$|\Delta p_n|_{\max} \cong p_{n0} \ll n_n \quad \dots \text{ for } x \geq x_n$$

(c) Since we have low level injection,

$$N_A \cong p_{p0} \cong p_p = 10^{14}/\text{cm}^3$$

$$N_D \cong n_{n0} \cong n_n = 10^{15}/\text{cm}^3$$

(d) Invoking the law of the junction,

$$n(-x_p)p(-x_p) = n_i^2 e^{qV_A/kT}$$

or

$$V_A = \frac{kT}{q} \ln \left[\frac{n(-x_p)p(-x_p)}{n_i^2} \right]$$

As deduced from Fig. P6.10,

$$n(-x_p) = 10^3/\text{cm}^3$$

$$p(-x_p) = 10^{14}/\text{cm}^3$$

and

$$n_i = \sqrt{n(\infty)p(\infty)} = \sqrt{n(-\infty)p(-\infty)} = \sqrt{10^{20}} = 10^{10}/\text{cm}^3$$

The foregoing manipulation to obtain n_i was necessary because the semiconductor used in fabricating the diode was not specified in the problem statement. Lastly, substituting into the V_A expression gives

$$V_A = (0.0259) \ln \left[\frac{(10^3)(10^{14})}{10^{20}} \right] = -0.18\text{V}$$

Q3 Under reverse bias $V_R = 1V$.

$$\phi_j = V_T \ln \left[\frac{N_A N_D}{n_i^2} \right] = 0.89V$$

$$\epsilon_s = \epsilon_r(\text{Silicon}) * \epsilon_0 = 11.68 * 8.85 * 10^{-14} \text{ F/cm} = 1.03 * 10^{-12} \text{ F/cm}$$

$$W_{do} = \sqrt{\frac{2\epsilon_s}{q} \left(\frac{1}{N_A} + \frac{1}{N_D} \right) \phi_j} = 15.4 \mu\text{m}$$

$$Q_{def} = \frac{q N_A N_D}{N_A + N_D} W_d A$$

$$= \frac{q N_A N_D}{N_A + N_D} A W_{do} \sqrt{\frac{1 + V_R}{\phi_j}}$$

$$\Rightarrow Q_{def} = 3.5 * 10^{-22} \text{ C}$$

Injection (Diffusion charge)

$$Q_D(V_D) = q A n_i^2 \left[\frac{W_p'}{2N_A} + \frac{L_p}{N_D} \right] (e^{qV_D/kT} - 1)$$

$$Q_D(-1V) = 2.13 * 10^{-53} \text{ C}$$

Q4 This is one-dimensional Gauss Theorem

let us begin by integrating Poisson eqn. from

$-T_p$ to T_n .

$$\int_{-T_p}^{T_n} \rho(x) dx = \int_{-T_p}^{-x_p} \rho(x) dx + \int_{-x_p}^{x_n} \rho(x) dx$$

$$+ \int_{x_n}^{T_n} \rho(x) dx$$

In the region $-T_p < x < -x_p$ and $x < x_n < T_n$ the charge density is zero.

The only integral that remains is

$$\int_{-x_p}^{x_n} \rho(x) dx = \int_{-x_p}^{x_n} \epsilon_s \frac{dE}{dx} dx = \int_{-x_p}^{x_n} \epsilon_s dE$$

$$= E(x_n) - E(-x_p) = 0 - 0$$

Total charge enclosed within space-charge layer is zero.

$$\frac{E_I - E_f}{\text{Intrinsic}} = kT \ln \frac{p_p}{n_i}$$

// //
Fermi-level

Inserting values $E_I - E_f = 470.74 \text{ meV}$.

Q6 For two materials, say material 1 and 2 having band-gap energies E_{g1} and E_{g2} , the ratio of their intrinsic carrier concentration is given by

$$\frac{n_{i1}}{n_{i2}} = \frac{\sqrt{N_{C1} N_{V1}} \exp[-E_{g1}/2kT]}{\sqrt{N_{C2} N_{V2}} \exp[-E_{g2}/2kT]}$$

$$= \sqrt{\frac{N_{C1} N_{V1}}{N_{C2} N_{V2}}} \exp\left[\frac{E_{g2} - E_{g1}}{2kT}\right]$$

Assuming differences in values of N_C and N_V are

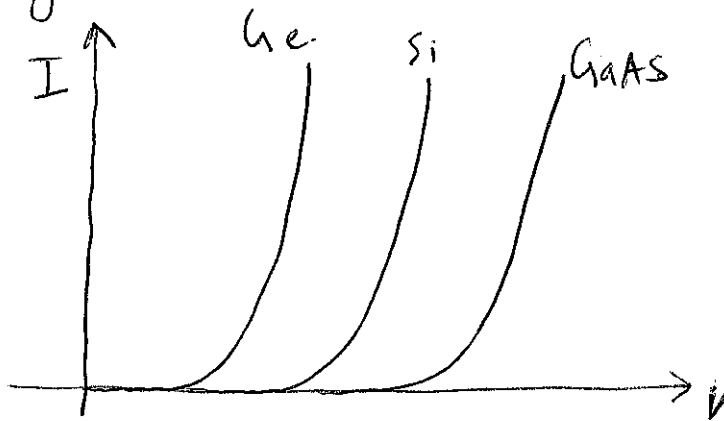
small $\Rightarrow \frac{n_{i1}}{n_{i2}} \approx \exp\left[\frac{E_{g2} - E_{g1}}{kT}\right]$

Considering the band-gap of the three materials:

$$\frac{n_i^2 \text{ Ge}}{n_i^2 \text{ Si}} \cong \exp\left[\frac{1.12 - 0.66}{0.026}\right] = 4.83 \times 10^{17}$$

Similarly, $\frac{n_i^2 \text{ Si}}{n_i^2 \text{ GaAs}} = 1.03 \times 10^5$

Since the other terms in expression for I_0 have much smaller dependence on the material, we can say that $(I_0)_{\text{Ge}} \gg (I_0)_{\text{Si}} > (I_0)_{\text{GaAs}}$



Close

1. Print the shipping label and the packing slip.
2. Cut out the shipping label and the packing slip.
3. Securely pack the items in a box or envelope and include the packing slip in the package.
4. Place the shipping label in a UPS Shipping Pouch. If you do not have a pouch, affix the label to your package using clear plastic shipping tape over the entire label. Take care not to cover any seams or closures on the package.
5. Take this package to a UPS location and mail it by January 28, 2012. To find your closest UPS location, visit the UPS Drop Off Locator or go to www.ups.com and select "Drop Off".