Electronic Devices

Tutorial-3: PN Junctions

Q. 1

Consider a silicon pn junction which is in equilibrium condition at room temperature having $N_a = 5X10^{17}/cm^3$ and $N_d = 10^{16}/cm^3$

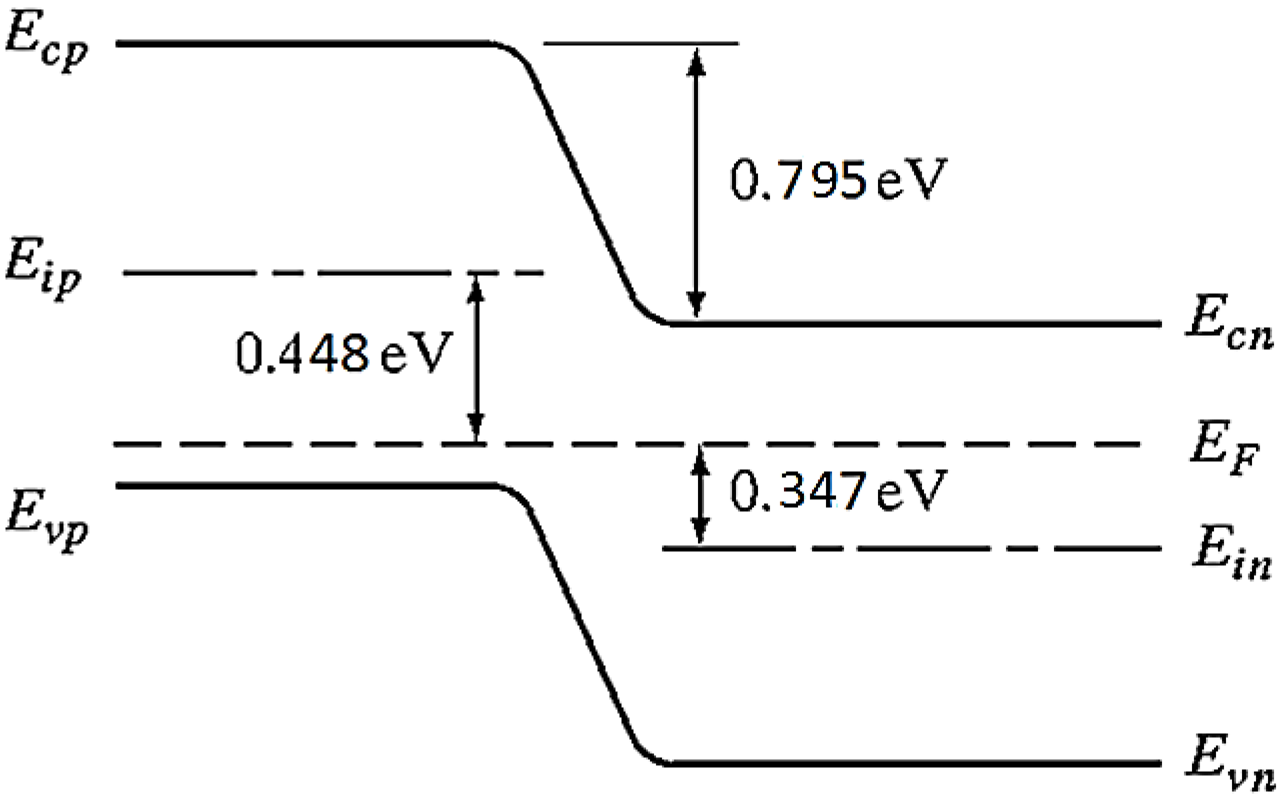
(a) Calculate the built-in potential at the junction
(b) Find out the Fermi level positions for p and n-region w.r.t the Fermi energy level of the junction
(c) Draw the equilibrium band diagram for the pn junction

$$V_0 = 0.795V$$

$$E_p - E_F = 0.4486eV$$

$$E_F - E_n = 0.347eV$$

(c) The band diagram at equilibrium,



Q. 2

A GaAs p-n junction has doping concentrations of N_d = $5X10^{16}/cm^3$ and N_a = $5X10^{15}/cm^3$. Consider that the junctions is not biased and at room temperature. Find out the values of width of transition region in n and p-region (x_{no}, x_{po}), the total width of depletion region, W and the value of maximum electric field developed at the junction, E_{max}. Given that the dielectric constant of GaAs, ε=12.9 and n_i=$1.8X10^6/cm^3$

$$W = 6.1 \times 10^{-5} cm$$

$$x_{n0} = 5.55 \times 10^{-6} cm$$

$$x_{p0} = 5.55 \times 10^{-5} cm$$

$$E_0 = -3.889 \times 10^{4} V/cm$$

Q. 3

A Si p^+-n junction, has a donor doping of 5×10^{16} cm^{-3} on the n side and a cross sectional area of 10^{-3} cm^2. If $\tau_p = 1$ µs and $D_p = 10$ cm^2/s, calculate the current with a forward bias of 0.5 V and a reverse bias of 0.6V at 300 K.

Sol.

Current under forward bias:

$$I = q \cdot A \cdot \frac{D_p}{L_p} \cdot p_n \cdot e^{\frac{q \cdot V}{kT}} = q \cdot A \cdot \frac{D_p}{\sqrt{D_p \cdot \tau_p}} \cdot \frac{n_i^2}{n_n} \cdot e^{\frac{q \cdot V}{kT}}$$

$$I = 1.6 \cdot 10^{-19} C \cdot 10^{-3} cm^2 \cdot \frac{10 \frac{cm^2}{s}}{\sqrt{10 \frac{cm^2}{s} \cdot 10^{-6} s}} \cdot \frac{(1.5 \cdot 10^{10} \frac{1}{cm^3})^2}{5 \cdot 10^{16} \frac{1}{cm^3}} \cdot e^{\frac{0.5eV}{0.0259eV}} = 0.55 \mu A$$

Current under reverse bias:

$$I = q \cdot A \cdot \frac{D_p}{L_p} \cdot p_n = q \cdot A \cdot \frac{D_p}{\sqrt{D_p \cdot \tau_p}} \cdot \frac{n_i^2}{n_n} \cdot$$

As the reverse bias is >>3KT

$I = 2.25 \times 10^{-15}$ A

Q. 4

A Si p-n junction with cross sectional area $A = 0.001 cm^2$ is formed with $N_a = 10^{15}/cm^3$ and $N_d = 10^{20}/cm^3$. Calculate:

(a) Contact Potential

(b) Space charge width at equilibrium

(c) Current with forward bias of 0.7 V. Assume that the current is diffusion dominated and the mobilities of electron and hole are 1350 cm^2/V-s and 450 cm^2/V-s respectively, the minority carriers lifetime 2.5 ms. Which carriers contributes more current?

Sol.

$$V_0 = \frac{kT}{q}\ln(\frac{N_a N_d}{n_i^2}) = 0.0259 \times \ln(\frac{10^{15} \times 10^{20}}{(1.5 \times 10^{10})^2})$$

$$= 0.873\ V$$

$$W = [\frac{2\varepsilon V_0}{q}(\frac{N_a + N_d}{N_a N_d})]^{1/2}$$

$$W = [\frac{2 \times 8.85 \times 10^{-14} \times 11.8 \times 0.873}{1.6 \times 10^{-19}}(\frac{10^{20} + 10^{15}}{10^{20} \times 10^{15}})]^{1/2}$$

$$W = [\frac{2 \times 8.85 \times 10^{-14} \times 12.9 \times 0.873}{1.6 \times 10^{-19}}(\frac{10^{20} + 10^{15}}{10^{20} \times 10^{15}})]^{1/2}$$

$$= 1.06 \times 10^{-4} cm$$

Sol.

$$I_D = q.A.(\frac{D_p}{L_p}p_{n0} + \frac{D_n}{L_n}n_{p0})(e^{\frac{V_f}{V_T}} - 1)$$

$Since\ p_{n0}$<<$n_{p0},$ as $N_A \ll N_D$

Current will be majorly contributed by the diffusion of electrons in p-region

$$D_n = \mu_n V_T\ = 1350 \times 0.026 = 35.1\ cm^2/s$$

$$L_n = \sqrt{D_n \tau_n}\ = \sqrt{35.1 \times 2.5 \times 10^{-3}} = 0.296\ cm$$

$$I \approx 1.6 \times 10^{-19} \times 0.001 \times \frac{35.1}{0.296} \times (\frac{(1.5 \times 10^{10})^2}{10^{15}}) \times (e^{\frac{0.7}{.026}} - 1)$$

$$I \approx (4.26 \times 10^{-15})(4.92 \times 10^{11})A = 2.1\ mA$$