ELECTRONIC DEVICES
ASSIGNMENT 6

AAKASH JOG
ID : 989323563

Exercise 1.
Consider a PN step junction at 300 K with

$$\begin{aligned} N_A &= 10^{16}\text{cm}^{-3} \\ N_D &= 10^{16}\text{cm}^{-3} \\ \tau_n &= 0.5\mu\text{s} \\ \tau_p &= 0.1\mu\text{s} \\ D_n &= 25\text{cm}^2\,\text{s}^{-1} \\ D_p &= 10\text{cm}^2\,\text{s}^{-1} \end{aligned}$$

Assume that a reverse bias of 5 V is applied. The junction is uniformly illuminated such that

$$G_{\text{optical}} = 10^{21}\text{cm}^{-3}\,\text{s}^{-1}$$

(1) Calculate the photocurrent J_{optical} in the junction.
(2) Calculate the total current density in the junction.
(3) Explain the biasing conditions for this illuminated PN junction for operation as a solar cell. Explain why using a PiN junction, instead of the basic PN structure can improve the device performance for solar cells.

Solution 1.
(1)

$$\begin{aligned} V_{\text{BI}} &= \frac{kT}{q}\ln\left(\frac{N_A N_D}{{n_i}^2}\right) \\ &= 0.026\ln\left(\frac{\left(10^{16}\right)\left(10^{16}\right)}{10^{20}}\right) \\ &= 0.026\ln\left(10^{12}\right) \\ &= (0.026)(27.63102112) \\ &= 0.7184065491\,\text{V} \end{aligned}$$

Date: Wednesday 20^{th} April, 2016.

Therefore,

$$\begin{aligned}
W &= \sqrt{\frac{2\varepsilon\varepsilon_0(V_{\mathrm{BI}} - V_a)}{q}\left(\frac{N_A + N_D}{N_A N_D}\right)} \\
&= \sqrt{\frac{(2)(11.8)\left(8.85 \times 10^{-14}\right)(0.72+5)}{1.6 \times 10^{-19}}\left(\frac{2 \times 10^{16}}{10^{32}}\right)} \\
&= \sqrt{\frac{(2)(11.8)\left(8.85 \times 10^{-14}\right)(5.72)}{1.6 \times 10^{-19}}\left(\frac{2 \times 10^{16}}{10^{32}}\right)} \\
&= 0.000122203\text{cm} \\
&= 1.2 \times 10^{-4}\text{cm}
\end{aligned}$$

Also,

$$\begin{aligned}
L_n &= \sqrt{D_n \tau_n} \\
&= \sqrt{(25)\left(0.5 \times 10^{-6}\right)} \\
&= 3.54 \times 10^{-3} \\
L_p &= \sqrt{D_p \tau_p} \\
&= \sqrt{(10)\left(0.1 \times 10^{-6}\right)} \\
&= 1 \times 10^{-3}
\end{aligned}$$

Therefore,

$$\begin{aligned}
J_{\mathrm{optical}} &= -qG_{\mathrm{optical}}\left(L_n + L_p + W\right) \\
&= -\left(1.6 \times 10^{-19}\right)\left(10^{21}\right)\left(3.54 \times 10^{-3} + 10^{-3} + 1.2 \times 10^{-4}\right) \\
&= -\left(1.6 \times 10^{-19}\right)\left(10^{21}\right)\left(4.66 \times 10^{-3}\right) \\
&= -0.7456\text{A}\,\text{cm}^{-2}
\end{aligned}$$

(2)

$$\begin{aligned}
J_{\mathrm{total}} &= q\left(\frac{D_p}{L_p}p_{N0} + \frac{D_n}{L_n}n_{P0}\right)\left(e^{\frac{qV_a}{kT}} - 1\right) + J_{\mathrm{optical}} \\
&= -q\left(\frac{D_p}{L_p}p_{N0} + \frac{D_n}{L_n}n_{P0}\right) + J_{\mathrm{optical}} \\
&= -q\left(\frac{D_p}{L_p}\frac{{n_i}^2}{N_D} + \frac{D_n}{L_n}\frac{{n_i}^2}{N_D}\right) + J_{\mathrm{optical}} \\
&= -\left(1.6 \times 10^{-19}\right)\left(\frac{10}{10^{-3}}\frac{10^{20}}{10^{16}} + \frac{25}{3.54 \times 10^{-3}}\frac{10^{20}}{10^{16}}\right) - 0.7456 \\
&= -\left(1.6 \times 10^{-19}\right)\left(10^{8} + 7.1 \times 10^{7}\right) - 0.7456 \\
&= -27.36 \times 10^{-12} - 0.7456 \\
&\approx -0.7456\text{A}\,\text{cm}^{-2}
\end{aligned}$$

(3) As the total current is negative, the junction works as a solar cell. If the junction is not in reverse bias, the current is not negative, and hence the junction does not function as a solar cell.
For a PiN junction, the width of the depletion region is larger. Hence, the

photocurrent is greater than that for a PN junction. Therefore, a PiN junction is better than a PN junction for use as a solar cell.