Detection of Light. Problem Set 5

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1 Diffusion in photodiodes

In a photodiode, the diffusion length L_n can be understood as the average distance a carrier can move (or diffuse) in the neutral p-type and n-type regions, before it recombines. As shown in the lectures, it is defined as:

$$L = (D\tau)^{1/2}$$

where

$$D = \frac{kT\mu}{q}$$

is the diffusion coefficient and τ is the recombination time.

a In order to increase detectability of photogenerated carriers, what condition would you impose to the thickness c of the neutral absorber layer overlying the depletion region, in terms of the impurity concentration? Assume that the variation of the mobility μ with the impurity concentration N_I is negligible and that $\tau \propto N_I^{-1}$.

b Test your condition by calculating the quantum efficiency:

$$\eta = \frac{2b}{e^{c/L} + e^{-c/L}}$$

for $c = L$ and $c = 2L$. b is the fraction of incident photons available for absorption to produce carriers. What do you conclude?

c On the other hand, what would be the requirement in the thickness c in terms of N_I in order to guarantee good absorption?

d Is it possible, in general, to meet these two conditions with extrinsic absorption?

2 Current and capacitance in a photodiode

Consider a photodiode equivalent to the one we designed in problem set 2. Operation temperature is 300 K. It has an area of 1 mm^2. Suppose the material is doped with $10^{15}\ \mathrm{cm}^{-3}$ As atoms in the n-type side. Assume a similar concentration of boron to make the p-type side. Compute:

a The diode current:

$$I_0 = qA\left(\frac{D_n^p}{L_n^p}p_n + \frac{D_p^n}{L_p^n}n_p\right)$$

$p_n = 1.9 \times 10^{11}\ \mathrm{m}^{-3}$ and $n_p = 2.5 \times 10^{10}\ \mathrm{m}^{-3}$. Assume again $\tau \propto N_I^{-1}$, and remember that in silicon $\tau = 1 \times 10^{-4}$ s for $N_I = 10^{12}\ \mathrm{cm}^{-3}$. Use $\mu_n = 1.35 \times 10^3\ \mathrm{cm}^2\ \mathrm{V}^{-1}\ \mathrm{s}^{-1}$ and $\mu_p = 480\ \mathrm{cm}^2\ \mathrm{V}^{-1}\ \mathrm{s}^{-1}$

b The capacitance C_j in absence of bias voltage. Assume a contact potential $V_0 = 0.58\,V$. What is C_j if a back-bias potential of $V_b = -1\,V$ is applied?