Applications: various P-N junction devices

Problem - 1

Assume that a photoconductor in the shape of a bar of length L and area A has a constant voltage V applied, and it is illuminated such that g_{op} EHP/cm^3-s are generated uniformly throughout. Since $\mu_n >> \mu_p$, we can assume the optically induced change in current ΔI is dominated by the mobility μ_n and life time τ_n for electrons. Show that $\Delta I = qALg_{op}\tau_n/\tau_\tau$ for this photoconductor, where τ_τ is the transit time of electrons drifting down the length of the bar.

Problem - 2

(a) Explain how making a p-i-n photo detector more sensitive to low light level degrades its speed?

(b) If this device is to be used to detect light with λ=0.6 μm, what material would one use?

Problem - 3

A solar cell 2 cm x 2cm with I_{th}=32 nA has an optical generation rate of 10^{18} EHP/cm^3-sec within L_p=L_n=2 μm of the junction. If the depletion width is 1 μm, calculate the short circuit current and the open circuit voltage for this cell.

Problem - 4

(a) A Si solar cell with dark saturation current I_{th} of 5 nA is illuminated such that the short circuit current is 200 mA. Plot the I-V curve for the cell.

(b) A major problem with the solar cells is internal resistance, generally in the thin region at the surface, which must be only partially contacted. Assume that the cell in (a) has a series resistance of 1 Ω, so that the cell voltage is reduced by IR drop. Replot I-V curve for this case and compare with that in (a).

Problem - 5

Sketch the band diagram of an abrupt p-n junction in which the doping on the p-side is degenerate and the Fermi level on the n-side is aligned with the bottom of the conduction band. Draw the forward and reverse bias band diagram and sketch I-V characteristic.

Problem - 6

Assume that a p^+-n junction is built with a graded n-region in which the doping is described by $N_d(x)=Gx^m$. The depletion region ($W \simeq x_{n0}$) extends from essentially the junction at x=0 to a point W within the n-region. The sigularity at x=0 for negative m can be neglected.

(a) Show that maximum electric field $\xi_0 = -qGW^{(m+1)}/\epsilon(m+1)$

(b) Find the expression for position dependent field and use the result to obtain $V_0 - V = qGW^{(m+2)}/\epsilon(m+2)$

(c) Find the charge Q due to ionized donors in the depletion region; write Q explicitly in terms of $V\text{-}V_0$.

(d) Using the results of (c), take the derivative $dQ/d(V\text{-}V_0)$ to show that the capacitance is

$$C_j = A\left\{\frac{qG\epsilon^{(m+1)}}{(m+2)(V_0-V)}\right\}^{(1/(m+2))}$$

Problem - 7

At a particular wave length of incident radiation, the absorption coefficients of Si and GaAs are 4000 per cm and 30,000 per cm, respectively. What are the thickness of Si and GaAs necessary to absorb 80% of the incident radiation?

Problem - 8

A 5 μm thick Si sample is illuminated with monochromatic light having $h\nu$=2 eV. The incident power is 10 mW.

(a) What is the total energy absorbed in the sample per second?

(b) How much energy per second is dissipated as heat?

(c) How many EHPs are generated in the sample per second?

Problem - 9

In their normal mode of operation, (choose the correct answer)

(A) a LASER is forward biased and a photodiode is reverse biased

(B) a LASER is reverse biased and a photodiode is forward biased

(C) both LASER and photodiode are forward biased

(D) both LASER and photodiode are reverse biased

Problem - 10

In their normal mode of operation,

(A) a LED is forward biased and a Zener diode is reverse biased

(B) a LED is reverse biased and a Zener diode is forward biased

(C) both LED and Zener diode are forward biased

(D) both LED and Zener diode are reverse biased

Problem - 11

Assume a p^+-n diode is biased in the forward direction, with a current I_f. At time t=0, the current is switched to $-I_r$. Solve for time dependent excess stored hole charge within the n-region. Find out the storage delay time, t_{sd}.