ELEC 321/4-H	INTRODUCTION TO SEMICONDUCTOR MATERIALS AND DEVICES	Winter 2018

Homework due on April 12th 2018

No late homework will be accepted

Questions marked with * are for extra credit!

Homework #6

1. A semiconductor, in thermal equilibrium, has a hole concentration of $p_0=10^{16}$ cm^{-3} and an intrinsic concentration of $n_i=10^{10}$ cm^{-3}. The minority carrier lifetime is 2×10^{-7} s. (a) Determine the thermal equilibrium recombination rate of electrons. (b) Determine the change in the recombination rate of electrons if an excess electron concentration of $\delta n=10^{12}$ cm^{-3} exists.

2. (a) A sample of semiconductor has a cross-sectional area of 1 cm^2 and a thickness of 0.1 cm. Determine the number of electron-hole pairs that are generated per unit volume per unit time by the uniform absorption of a 1 Watt of light at a wavelength of 6300 Å. Assume each photon creates one electron-hole pair. (b) If the excess minority carrier lifetime is 10 μs, what is the steady state excess carrier concentration?

3. * Consider a one-dimensional hole flux as shown in Fig. 6.4 of your text (page 9 of the lecture notes). If the generation rate of holes in this differential volume is $g_p=10^{20}$ cm^{-3}-s^{-1} and the recombination rate is 2×10^{19}cm^{-3}-s^{-1}, what must be the gradient in the particle current density to maintain a steady-state hole concentration?

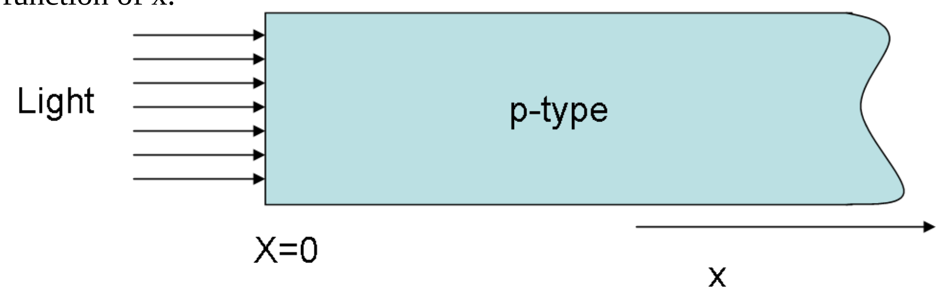
4. Consider a homogeneous GaAs semiconductor at T=300 K with $N_a=10^{16}$ cm^{-3} and $N_d=0$. A light source is turned on at t=0 producing a uniform generation rate of $g'=10^{20}$ cm^{-3}s^{-1}. The electric field is zero. (a) Derive the expression for the excess-carrier concentration and excess carrier recombination rate as a function of time. (b) If the maximum, steady state, excess carrier concentration is to be 10^{14} cm^{-3}, determine the maximum value of the minority carrier lifetime. (c) Determine the times at which the excess minority carrier concentration will be equal to (i)three-fourth, (ii) one-half, (iii) one-fourth of the steady state value.

5. Consider a bar of p-type silicon that is homogeneously doped to a value of 3×10^{15} cm^{-3} at T=300 K. The applied electric field is zero. A light source is incident on the end of the semiconductor as shown in figure below. The excess carrier concentration generated at x=0 is $\delta p(0)=\delta n(0)=10^{13}$ cm^{-3}. Assume the following parameters (neglect surface effects):

$\mu_n=1200$ cm^2/V-s, $\tau_{n0}=5\times10^{-7}$ s

$\mu_p=400$ cm^2/V-s, $\tau_{p0}=10^{-7}$ s

(a) Calculate the steady state excess electron and hole concentrations as a function of distance into the semiconductor. (b) Calculate the electron diffusion current density as a function of x.



6. * Consider the semiconductor described in problem 5. Assume a constant electric field E_0 is applied in the +x direction. (a) Derive the expression for steady state excess electron concentration. (Assume the solution is of the form e^{-ax}.) (b) Compare this formula with the one of E=0 and explain the general characteristics of the two expressions (i.e. with and without electric field).

7. * Assume that a p-type semiconductor is in thermal equilibrium for t<0 and has an infinite minority carrier lifetime. Also assume that the semiconductor is uniformly illuminated, resulting in a uniform generation rate, $g'(t)$, which is given by G'_0 for $0<t<T$ and zero at other times. G'_0 is a constant. Find the excess minority carrier concentration as a function of time.

8. An n-type silicon sample with $N_d=10^{16}$ cm^{-3} is steadily illuminated such that $g'=10^{21}$ cm^{-3}-s^{-1}. If $\tau_{n0}= \tau_{p0}=10^{-6}$ s, calculate the position of the quasi-Fermi (or Imref) levels for electrons and holes with respect to the intrinsic level (assume that $n_i=1.5\text{x}10^{10}$ cm^{-3}). Plot these levels on the energy-band diagram.