ECE 132 Fall 2018

UNIVERSITY OF CALIFORNIA, SANTA BARBARA

Department of Electrical and Computer Engineering

Homework 3 – due November 6, 2018 by 5:00pm

1. Electrons are injected into a p-type semiconductor slab which is 5 microns long in such a way that the electron concentration varies linearly from 10^{20} cm^{-3} on the left to 0 on the right. If the mobility of the electrons is 500 cm^2/V·s and electrons are continuously supplied to maintain this profile, assuming electric fields are negligible, what is the current density flowing through the slab?

2. We have seen that when an entire piece of n-type semiconductor is under constant illumination by a light source which creates electron-hole pairs at a rate g_{op} throughout the semiconductor, the steady-state minority carrier concentration (i.e., hole concentration p) is given by $p = g_{op}\tau_p$, where τ_p is the hole carrier lifetime. Assume a silicon sample is doped with a concentration $N_D = 10^{15}$ cm^{-3} of shallow donors. Prior to time $t = 0$, the sample is at thermal equilibrium. Starting at time $t = 0$, the sample is illuminated constantly by a light source which generates electron-hole pairs at a rate $g_{op} = 10^{16}$ EHP/(cm^3·s) throughout the sample. If the hole carrier lifetime $\tau_p = 1\ \mu$s, calculate (a) the steady-state hole concentration p_{fin}, (b) the time required for p to increase from its equilibrium value to $(0.1)p_{fin}$, and (c) the time required for p to increase from its equilibrium value to $(0.9)p_{fin}$.

3. We continuously shine light at the surface ($x = 0$) of a p-type semiconductor, generating 10^{20} EHP/(cm^3·s) at the surface only. The excess EHPs diffuse into the sample, and the light also causes the entire sample to heat up to a temperature of 500 K. If the minority carrier lifetime in the sample is 200 ns (for both electrons and holes), the electron mobility is 2000 cm^2/V·s, and the hole mobility is 500 cm^2/V·s, calculate the electron diffusion current density 20 microns from the surface.

4. An abrupt Si *p*-*n* junction has $N_D = 10^{16}$ cm^{-3} on the *n* side and $N_A = 10^{16}$ cm^{-3} on the *p* side. For Si at room temperature, E_G = 1.1 eV, N_C = 2.8 x 10^{19} cm^{-3}, and N_V = 1.8 x 10^{19} cm^{-3}.

   (a) Calculate the position of the Fermi level at 300 K in the bulk *n* and *p* regions (i.e., calculate E_C-E_F in the bulk *n* region and E_F-E_V in the bulk *p* region).

   (b) Draw the equilibrium band diagram for the junction. Determine the built-in potential V_{bi} from the diagram.

5. Reading Assignment: *Streetman*: Ch. 4 (all) and Ch. 5 (sections 5.2 and 5.3)