3.15 Electrical, Optical, and Magnetic Materials and Devices
Caroline A. Ross
Fall Term, 2006

Problem Set #1 Semiconductor Fundamentals

Due Monday, September 18, 2005

Reference: Chapters 1-3 of Pierret.

1. Review of 3.024. Write a brief (1 line) definition for each of the following:

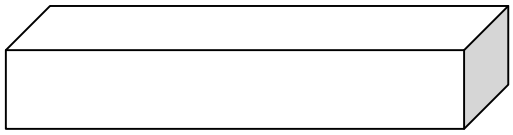
conduction & valence bands	drift velocity
band gap	thermal motion
effective mass	drift current
intrinsic & extrinsic semiconductors	mobility
dopant	resistivity or conductivity
donors & acceptors	diffusion
n-type & p-type materials	diffusion current
n^+ (or p^+) material	diffusion coefficient
majority & minority carriers	recombination & generation
density of states	direct thermal R-G
Fermi function	photogeneration
Fermi energy (or level)	steady state
degenerate semiconductor	equilibrium
extrinsic & intrinsic temperature regimes	minority carrier lifetime
freeze-out	minority carrier diffusion length

2. a) Draw sketches showing $g_c(E)$, $g_v(E)$, f(E) and the carrier distributions for a semiconductor that is (i) intrinsic, (ii) n-type. (make the sketches with the E axis vertical.)

b) Germanium has the same crystal structure as silicon but its band gap is 0.67 eV.If the total density of states in the conduction band (N_c) and in the valence band (N_v) are the same as they are for silicon, what value of n_i would you expect for Ge at 300K?

c) The Ge is now doped with B and with P. Both dopants have the same concentration. Assume the B and P energy levels are each 40 meV from the band edge. If $m_n^*/m_p^* = 0.01$, draw the band diagram of the doped Ge as accurately as you can, showing E_g, E_f and E_i.

3. a) What factors affect the mobility of a carrier? (2-3 sentences)
b) A piece of p-type Si with $N_A = 10^{18}$ cm^{-3} and a length of 1 cm is heated at one end. This affects the value of n_i as follows:



Hot
$n_i = 10^{12}$ cm^{-3}

Cold
$n_i = 10^{10}$ cm^{-3}

Consider only the electrons in the Si, neglecting the motion of the holes. Where do drift and diffusion of the electrons occur? Estimate the electric field at the cold end of the Si.

4. Si and Ge can be mixed together to form a Si_xGe_{1-x} semiconductor material. The band gap increases linearly with x, from the value for pure Ge at x = 0 to the value for pure Si at x = 1. You have a bar of intrinsic SiGe material, with x = 0.2 at one end and x = 0.8 at the other end. The composition varies linearly with distance. Draw the equilibrium band structure in as much detail as you can and explain whether there is any drift or diffusion or R&G taking place in the material. (this should be a short answer)

5. Light is flashed onto the surface of a piece of intrinsic semiconductor very quickly, then the light is turned off. Draw a sketch to show how the concentration of carriers varies with distance into the semiconductor, at different times after the light is turned off. Give an expression that describes this behavior (note – you do not have to solve this equation, just explain the various terms). What determines the recombination rate?