Homework #4 - EE 482

due 1/31/11

1. A 1 Ω-cm p-type silicon sample contains 10^{12}cm^{-3} generation-recombination centers located 0.1eV below the intrinsic Fermi level with $\sigma_n = \sigma_p = 10^{-15}\text{cm}^2$, $v_{thn} = 10^7\text{s}^{-1}$ and $v_{thp} = 6 \times 10^6\text{s}^{-1}$. $T = 300\text{K}$.
   (a) If incident radiation creates $10^{18}\text{cm}^{-3}\text{s}^{-1}$ hole-electron pairs throughout the sample, what are the carrier concentrations during irradiation?
   (b) Repeat (a) for $10^{24}\text{cm}^{-3}\text{s}^{-1}$ hole-electron pairs created.
   (c) Calculate the generation rate in this sample if the minority carrier concentration has instead been **reduced** (i.e. extraction) well below its equilibrium value ($n \ll n_0$) without significant change in the majority carrier concentration.

2. A given piece of p-type silicon 600μm thick has a uniform acceptor concentration of $10^{17}\,\text{cm}^{-3}$. The sample is irradiated so that hole-electron pairs are generated uniformly at a rate of $10^{18}\,\text{cm}^{-3}\text{s}^{-1}$ throughout the sample. At the top and bottom surfaces, the recombination velocity is $10^3\,\text{cm/s}$. Assume $\tau_n = 10\,\mu\text{s}$, $\tau_p = 16\,\mu\text{s}$ and $T = 300\text{K}$.
   (a) Calculate and sketch the concentrations of holes and electrons as a function of distance. Assume that the diffusion approximation is valid for excess minority carriers.
   (b) What is the concentration of carriers at the top surface? What percentage of the light-generated carriers recombine at the two surfaces (rather than in the bulk)?
   (c) Check the diffusion approximation at the top surface by determining the electric field near the surface to make majority and minority currents equal and using it to calculate minority carrier drift current.

3. Aluminum (work function 4.1eV) is in contact with silicon (electron affinity 4.05eV) doped with 10^{17}cm^{-3} of arsenic at room temperature.
   (a) Ignoring surface states, calculate the work function of the silicon ϕ_s, the metal-semiconductor barrier height ϕ_B and the built-in voltage ϕ_i and draw the theoretical equilibrium energy-band diagram. Is this contact blocking or ohmic? Explain.
   (b) Repeat (a) assuming that a very large number of surface states (both donors and acceptors) exist centered 0.4eV above the valence band. Assume that the interface layer is thin enough to allow easy tunnelling and can be ignored in calculating the barriers.
   (c) Sketch the band diagram for these two contacts assuming that there is +0.2V bias on the semiconductor relative to the metal.