Homework #3 - EE 482

due 10/23/02

1. At room temperature, the scattering lifetime for holes in a given material is 3 ps and ionized impurity scattering and lattice scattering are equally probable.

   (a) The temperature is changed in such a way that the probability of lattice scattering is halved and the probability of scattering due to ionized impurities increased by factor of 1.5. What is the new total scattering time and was the temperature raised or lowered?

   (b) If the hole effective mass is $0.5m_0$ and $n = 10^{17}\text{cm}^{-3}$, what would be the average drift velocity and current density at each of these temperatures in an applied field of $\mathcal{E} = 1000\text{V/cm}$ $(0.1\text{V}/\mu\text{m})$?

   (c) What is the maximum current density in this material doped as above if the hole velocity saturates at $6 \times 10^6\text{cm/s}$?

2. An integrated circuit resistor is made by diffusing arsenic into a silicon substrate doped with $N_a = 2\times10^{17}\text{cm}^{-3}$ of boron. The resulting boron profile has a peak doping at the surface equal to 10^{18}cm^{-3} and a junction depth of $0.1\mu\text{m}$. The total integrated dose of arsenic within $0.1\mu\text{m}$ of the surface is 6×10^{12} cm^{-2}. Note: Don't overlook compensation.

   (a) What is the resistivity of the substrate?

   (b) What is the **approximate** sheet resistance of the diffused layer?

   (c) What is the resistance for resistor $0.5\mu\text{m}$ wide and $2\mu\text{m}$ long (ignore contact resistance)?

3. A sample of GaAs (a direct band-gap semiconductor) with an acceptor concentration of 10^{16}cm^{-3} is irradiated continuously by photons of sufficient energy to create hole-electron pairs. The GaAs is kept at room temperature.

   (a) Given that the generation due to photons is spatially uniform at $10^{20}\text{cm}^{-3}\text{s}^{-1}$, find the excess carrier concentrations and the percent change in each type caused by the light if $K = 10^{-8}\text{cm}^3/\text{s}$

   (b) The light is turned on at $t = t_0$. Plot the change in hole and electron concentrations as a function of time for $t > t_0$. When will the excess electron concentration increase to 50% of its steady-state value?

   (c) Repeat (a) for uniform generation of $10^{26}\text{cm}^{-3}\text{s}^{-1}$. What is the resistivity of the sample during this irradiation and with no irradiation?

4. A given piece of n-type silicon $100\mu\text{m}$ thick has a uniform donor concentration of 10^{17}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 10^5cm/s. Assume $\tau_n = 10\,\mu\text{s}$, $\tau_p = 20\,\mu\text{s}$ and $T = 300\text{K}$.

   (a) Calculate and sketch the concentrations of holes and electrons as a function of distance. You may 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 top surface?

5. 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.