Homework #3 - EE 482

due 1/24/11

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 $p = 10^{17}\text{cm}^{-3}$, 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. A constant built-in electric field, $E = 100$ V/cm, exists in the $+x$ direction across an n-type GaAs sample for $0 \le x \le 20\mu\text{m}$. The total electron current density is a constant at $J = 100\text{A/cm}^2$. At $x = 0$, the drift and diffusion currents are equal. If T=300K and $\mu_n = 8000$ cm^2/Vs,

   (a) Set up an expression for the total current density in terms of the electron concentration and gradient.

   (b) Calculate the electron concentration at x=0 and at x=20um, and the drift and diffusion current densities at 20um.

3. An integrated circuit resistor is made by diffusing arsenic into a silicon substrate doped with $N_a = 2 \times 10^{17}\text{cm}^{-3}$ of boron. The resulting arsenic profile has a peak doping at the surface equal to 10^{18}cm^{-3} and a junction depth of 20 nm. The total integrated dose of arsenic within 20 nm of the surface is 1.5×10^{12} cm^{-2}. Note: Don't overlook compensation.

   (a) What is the resistivity of the substrate?

   (b) /bf Estimate the sheet resistance of the diffused layer?

   (c) What is the required aspect ratio (W/L) to make resistor of 100 kΩ? (ignore contact resistance)?

4. A sample of GaAs (a direct band-gap semiconductor) with an acceptor concentration of 10^{17}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 $10^{28}\text{cm}^{-3}\text{s}^{-1}$. What is the resistivity of the sample during this irradiation and with no irradiation?