ECE609 Spring07

# HOMEWORK 3

Physics of semiconductors- PN junctions

## 1 Semiconductors Fundamentals (40pts)

15pt A GaAs semiconductor is doped with $2.3 * 10^{17}$ donors per $cm^{-3}$, calculate the electron and hole concentration at equilibrium. Calculate $(E_c - E_F)$ without using a formula involving $N_c$. What is the occupancy of an electron inside the conduction band with an energy $E_1 - E_c = 0.0693eV$ and $E_2 - E_c = 0.277eV$.

25pt A 9nm thick layer of GaAs is sandwiched between two larger bandgap AlGaAs layers (see Fig. 1). Find the allowed energy levels (in $eV$) within the finite square well potential formed in the conduction band and in the valence band (use $E_g = 2.03eV$ for AlGaAs). You will make use of the formula derived for the infinite well potential case (no derivation is required). Sketch a graph to summarize the obtained results.

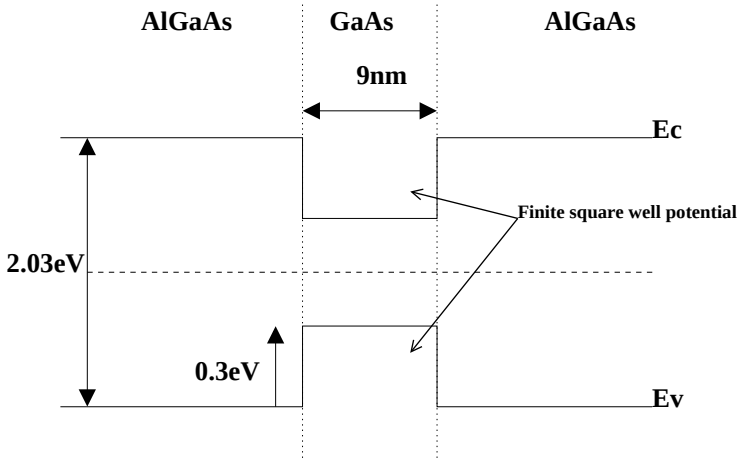


Figure 1: AlGaAs/GaAs/AlGaAs

## 2 Theory of Electrical Conduction (20pts)

5pt Electrons in undoped gallium arsenide have a mobility of $8,800cm^2/V.s$. Calculate the average time in picosecond between collisions (we will use $0.067m_0$ for the effective mass of the electrons). Calculate the distance traveled between two collisions in nanometer (also called the mean free path). Use an average velocity of $10^7 cm/s$.

5pt A piece of silicon is doped with boron ($N_a = 10^{17}cm^{-3}$). Calculate the resistivity of this P-type semiconductor (we consider $317cm^2/V.s$ for the mobility).

10pt The hole density in an N-type silicon wafer ($N_d = 10^{17}cm^{-3}$) decreases linearly from $10^{14}cm^{-3}$ to $10^{12}cm^{-3}$ between $x = 0$ and $x = 1.5\mu m$. Calculate the hole diffusion current density at $T = 300K$ (the hole mobility is equal to $317cm^2/V.s$).

## 3 P-N junctions [40pt]

5pt A semiconductor diode is fabricated from GaAs with $N_a = 10^{12} cm^{-3}$ on the p-side and $N_d = 10^{9} cm^{-3}$ on the n-side. What are the built-in potential and width of the depletion region (in $\mu m$)?

15pt Consider the same P-N junction than above. If the reverse saturation current of this ideal diode is measured to be $J_s = 10^{-12} A/m^2$, what are the forward currents for applied biases of $0.5V$ and $1.0V$. What is the excess electron concentration at the edge of the P-side for both cases ?

15pt Sketch the variation of the conduction band, valence band, Fermi-level, Intrinsic Fermi-level of the P-N junction. Sketch the direction of the drift and diffusion currents both for the electrons and holes.

5pt We set $N_d = 10^{19} cm^{-3}$, $l_p = 1.03 \mu m$(size of the depletion region in the P-region), what is the value of $l_n$ if we consider $N_a = 10^{15}$ ? Comment.