ECE 416/516 Simulation Assignment #1: Semiconductors (100 points) **Due 10/28/16 5PM**

This assignment is intended to demonstrate some of the basic properties of semiconducting materials with the utilization of Matlab and SILVACO Atlas simulation tools. For all plots you produce, label carefully each of the curves and all axes. Also remember that the dependent value goes on the y-axis and to use logarithmic scales when appropriate. Discuss the expected effect of temperature and material choice where relevant. Assume Si at T = 300K unless otherwise specified.

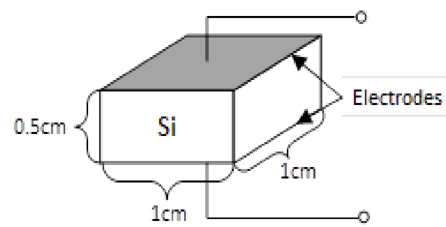
1) Matlab (50 points):

a) 10 points - Plot energy level vs. the occupation probability for electrons in a material at **T = 0, 100 200, 300, and 400 K**. Comment on the implications for electrical properties in materials. (Hint: see examples in the book. For the T at 0, please use 0.01 instead of 0 otherwise you won't get an appropriate graph.)

b) 10 points - Using the empirical equations* below for Si at 300K, plot electron and hole drift mobilities (μ_n and μ_p) as a function of doping concentration (N_x) for $\mathbf{N_x = 10^{12}}$ **to** $\mathbf{10^{20}\ cm^{-3}}$. Present on one graph.

$$\mu_n \approx 88 + {}^{1252}\!/_{(1 + 6.948 \times 10^{-18}\, N_x)} \ {}^{cm^2}\!/_{Vs} \qquad \mu_p \approx 54.3 + {}^{407}\!/_{(1 + 3.745 \times 10^{-18}\, N_x)} \ {}^{cm^2}\!/_{Vs}$$

c) 30 points - Using the mobility equation from part 1(b) generate current vs. voltage (I-V) curves for 0-10 V for the test structure shown. Do this first for N_A and then for N_D at doping levels of $\mathbf{0, 10^{12}, 10^{14}}$**, and** $\mathbf{10^{18} cm^{-3}}$ (8 curves total). Tabulate resistivity values for each. Present your results on one log-log plot and clearly indicate dopant type and concentration for each curve. Assume non-degenerate conditions.



2) ATLAS (50 points):

a) Using the structure file provided, generate three I-V curves for the sample from part 1(c) with (i) $\mathbf{N_A = 10^{18}\ cm^{-3}}$, (ii) $\mathbf{N_D = 10^{18}\ cm^{-3}}$, and (iii) $\mathbf{N_A = 10^{18}}$ ***and*** $\mathbf{N_D = 1.7 \times 10^{18}}$ (this is called "counter doping" or "compensation doping"). Produce the same curves for germanium (Ge) and indium arsenide (InAs). Tabulate resistivity values and provide one plot for each material. Compare the results for Si to the Matlab results from 1(c).

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For Si at each doping level used in 2(a), extract and tabulate resistivity values for concentration and mobility of electrons and holes at 100, 200, and 500 K.

Manually calculate the resistivities you would expect for the device using the Boltzmann approximation for scenario (ii) above as well as for $\mathbf{N_D = 10^{17}}$ and $\mathbf{N_D = 10^{19}}$. Use ATLAS to simulate these devices and extract the resistivity. Compare your calculated and simulated resistivities and explain differences if any.

Report

Every table and graph should be followed by a detailed explanation. Discuss the results of each plot/table and explain the physical causes of any trends you see. Please be detailed. For example "conductivity increases with doping" is not sufficient. Explain how and why this is so. Do not forget to label all units in plots and tables. All code with comments should be included as an appendix to the report. **Please use color. There is a penalty of two points off per day for late submission.**

* Empirical fits from S. O. Kasap, *Principles of Electronic Materials and Devices*, McGraw Hill 2009.