PY4118 Physics of Semiconductor Devices

Assignment #3

Due: October 17, 2017

For parameters, use: http://www.ioffe.rssi.ru/SVA/NSM/Semicond/
Assume the temperature is 300K unless otherwise stated.

Question 3.1

[3 marks] Use the effective masses of silicon (*use the effective mass of density of states*) plot the intrinsic carrier density - n_i as a function of temperature for silicon from 100-400K. Use a y-log axis, but only show physically meaningful results. At what temperature is $n_i \geq 1cm^{-3}$?

- This question should give you a sense of how carriers are thermally generated

Question 3.2

[3 marks] Still using the effective masses from 3.1, consider the intrinsic carrier density at 300K for bandgaps ranging from 0.1 to 8 eV. Use a log axis plot the range that has physically meaningful, and explain why other regions are not meaningful. At what bandgap are will $n_i \leq 1cm^{-3}$?

- This question should give you a sense of the transition between a semi-metal through a semiconductor into an insulator.

Question 3.3

[4 marks] Using the silicon parameters as in the previous questions at 300K, consider p-doped silicon. Use the Boltzman approximation in estimating carrier densities. When the Fermi level is exactly 3kT from the valence band:

a) [2 marks] What is the doping level? (in cm^{-3})
b) [2 marks] What proportion of the silicon crystal is a dopant?

- This question should give you a sense of actual proportion of atoms used in doping levels

Question 3.4

[4 marks] 3.3 volts is applied across a 0.25 micron long silicon region. Provide the drift velocity and transit time (i.e. how long do the carriers take to move the 1 micron) for both electrons and holes. (Don't worry about saturation velocity in your answer, although it is worth noting)

- This question is designed to demonstrate typical speeds of carrier transit

Question 3.5

[3 marks] Compare InAs and silicon transistors, both using electrons as active carriers. Current silicon ICs can be made with 14nm gate lengths (or less). What gate length must an InAs transistor have to achieve the same performance (i.e. the time taken for the carriers to transverse the gate region) *if the same voltage is applied across the region*? (assume no saturation voltage)

- This question should help explain why InAs is of interest as a material for ultra-fast electronics.

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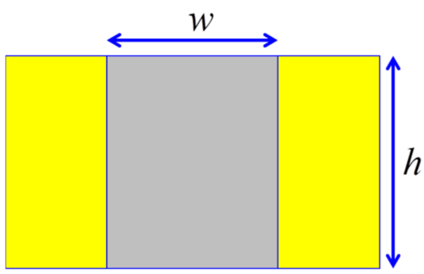
Question 3.6

[2 marks] In p-type GaAs, electrons are injected into the sample from a contact. If the electron mobility is $4000\ cm^2/V \cdot sec$, and the recombination time is $0.6\ nsec$, ***calculate*** (i.e. do not find a value) the diffusion constant (D_n) and the diffusion length (L_n) for the electrons.

Question 3.7

[3 marks] Silicon is p-doped with $N_A = 1 \times 10^{16} cm^{-3}$. Two metal contacts are made to each side of the silicon layer as shown in the figure, where $h = 5w$.



a) [2 marks] If the silicon layer is $0.2\mu m$ thick, what resistance will be measured between the contacts?
b) [1 marks] What is the population density of electrons?

Question 3.8

[4 marks] The structure of question 3.7 has: $5w = h = 100\mu m$. If $5mW$ of light from a Blu-ray laser (use $420nm$) is fully absorbed by the silicon, and each photon generates an electron hole pair:

a) [2 marks] What is the population density of the electrons assuming the recombination time is 5 nsec?
b) [2 marks] What resistance value will now be measured between the contacts?