ELEC-3140 Semiconductor physics Nov 9, 2021

Exercise 5: Density of states, carrier statistics

1. A semiconductor structure, in which the charge carriers can only move in one dimension, is called a quantum wire. Therefore, the structure has energy barriers and small dimensions in the other two dimensions to create the confinement. Calculate the density of states function for a quantum wire with the width L_x, the height L_y and the length L_z ($L_z >> L_x, L_y$).

2. Calculate the energy at which the electron distribution of a parabolic conduction band has its maximum in a 3-dimensional non-degenerate (not highly doped) semiconductor crystal. Use the Maxwell-Boltzmann distribution.

3. Calculate the electron and hole densities in intrinsic GaAs at T = 300 K and T = 500 K. The effective masses are $m_e^* = 0.067\,m_0$ ja $m_h^* = 0.45\,m_0$ and the general temperature dependence of the band gap (Varshni equation) is

$$E_g\left(T/K\right) = E_g\left(0\right) - \frac{\alpha T^2}{T+\beta} \ ,$$

where for GaAs: $E_g\left(0\right) = 1.519$ eV, $\alpha = 5.405 \cdot 10^{-4}$ eV/K, $\beta = 204$ K.

4. Silicon contains $8 \cdot 10^{16}\ \text{cm}^{-3}$ arsenic atoms and $2 \cdot 10^{16}\ \text{cm}^{-3}$ boron atoms. Calculate the electron and hole concentrations at thermal equilibrium. Calculate also the position of the Fermi level compared to intrinsic Fermi level E_{Fi} and to the conduction band minimum E_C. Si (T = 300 K): $n_i = 1.5 \cdot 10^{10}\ \text{cm}^{-3}$ ja $N_c = 2.8 \cdot 10^{19}\ \text{cm}^{-3}$.