ELEC-3140 Semiconductor physics **Oct 19, 2021**

Exercise 3: Energy band structure, pseudomorphic layers

1. Let the hypothetical energy band dispersion of a material be

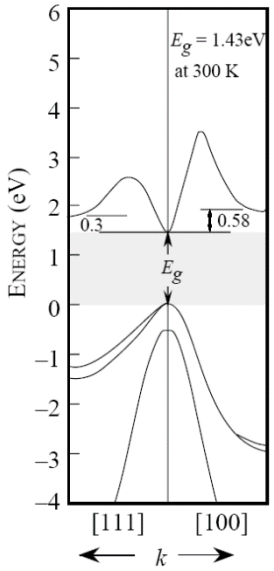
$$E(k) = E_0\left[1 - e^{-2a^2k^2}\right] \quad ,$$

where a is the lattice constant of the material. Calculate a) the effective mass with the wave vector value of $k = 0$. b) At what value of the vave vector k does the electron have the highest speed? (Use group velocity $v_g = \frac{d\omega}{dk}$) , c) Calculate the effective mass at the edge of the Brillouin zone.

2. The conduction band of GaAs changes from parabolic to non-parabolic fairly close to the conduction band minimum E_C. The energy is more accurately described by equation:

$$E - E_C = ak^2 - bk^4 \qquad (a>0, b>0)$$

a) Derive an expression for the effective mass m_e^* in the conduction band.
b) Calculate m_e^* at the conduction band minimum.
c) The electrons in GaAs can move from Γ minimum to L minimum if the electric field applied over the structure is sufficiently large. (Band structure of GaAs in the figure.) Describe qualitatively how the electron effective mass changes.



3. Pseudomorphic $Ga_{0.50}In_{0.50}As$ and $Ga_{0.2}In_{0.8}As_{0.4}P_{0.6}$ layers have been grown epitaxially on an InP substrate. a) Calculate the lattice constants of the free-standing layer materials. b) Calculate the relative lattice mismatch of the layer materials on an InP substrate. c) Calculate the vertical component of the lattice constant of the layer materials on the substrate.

4. Calculate the bandgap energy and the corresponding wavelength for a) $Ga_{0.47}In_{0.53}As$ and b) $Ga_{0.2}In_{0.8}As_{0.4}P_{0.6}$. These compositions are nearly lattice matched to InP and, therefore, can be used in InP-based devices.