# ELEC-3140 Semiconductor physics Nov 2, 2021

## Exercise 4: Strain, quantum structures

1. An epitaxial $Ga_xIn_{1-x}As$ layer having a composition of x = 0.8 is grown on a GaAs substrate. Assume that the layer is completely pseudomorphic. What is the band gap energy of the GaInAs layer and the corresponding wavelength, if the effects of strain are excluded?

2. Assume the similar situation as in the problem 1. Assume also that the elastic constants for GaInAs are approximately the same as for GaAs. What is the band gap energy of the GaInAs layer and the corresponding wavelength, when the effects of strain are taken into account?

3. Consider a quantum well structure formed a $Ga_{0.47}In_{0.53}As$ well with InP barriers (lattice matching condition, no strain). a) Calculate electron and heavy hole effective masses for $Ga_{0.47}In_{0.53}As$ (linear interpolation from the effective masses of the binary compounds). b) Calculate the band gap energy of $Ga_{0.47}In_{0.53}As$ (remember to utilize the bowing parameter). c) Calculate the energy and the corresponding wavelength for the 1e-1hh transition, when the well thickness is 40 Å. Use infinite barrier approximation for the quantization energies.

4. Using the equations for the energy levels of quantum wells (the transcendental equations from the lecture slides or from the extra problem below) solve the numerical values for a $Ga_{0.2}In_{0.8}As_{0.4}P_{0.6}$ quantum well having InP barriers and with a band gap of 1.12 eV and effective masses of $m_e^* = 0.06424\, m_0$ and $m_h^* = 0.4324\, m_0$ numerically or graphically. Assume that the discontinuity of the potential is divided 50:50 between the conduction and valence bands. Calculate also the wavelength corresponding to the energy of the 1e–1hh transition when the well width is 6 nm.

## Extra problem

5. Consider a quantum well structure with the well material having a smaller band gap than the barriers. Assume a type I interface and that the band gaps are aligned so that the discontinuity of the conduction edge is equal to that of the valence band using discontinuity value of $V_0$. Calculate the expression for the energy levels in the well (you arrive at the transcendental equations shown in the lecture). The key condition to get to the solution is to demand, that both the wavefunctions $\psi_n(z)$ (the wavefunction penetrates from the well region also to the barriers regions) and their normalized first derivatives $\frac{1}{m^*(z)} \frac{\partial \psi_n(z)}{\partial z}$ are continuous at the well-barrier interface.