Energy Band Structure for Strained GaInAs

The energy-band structure in the momentum space for a bulk Ga$_{x}$In$_{1-x}$As material under (a) biaxial compression, (b) lattice-matched condition, and (c) biaxial tension for different Ga mole fractions $x$. The heavy-hole band is above the light-hole band and its effective mass in the transverse plane (the $k_x$ or $k_y$ direction) is lighter than that of the light-hole band in the compressive strain case in (a). The light-hole band shifts above the heavy-hole band in the case of tension in (c).
Energy Band Gap for Strained GaInAs

The energy band gap of a bulk In$_{1-x}$Ga$_x$As vs. the Ga mole fraction $x$:
- unstrained In$_{1-x}$Ga$_x$As;
- transition energies from the conduction band (C) to the heavy-hole (HH) and light-hole (LH) bands for a bulk In$_{1-x}$Ga$_x$As pseudomorphically grown on InP;
- the conduction to light-hole transition energy calculated without the spin-orbit (SO) split-off band coupling.

E-k Relation and Effective Masses

\[ P_{\varepsilon} = -a_{\varepsilon} (\varepsilon_{xx} + \varepsilon_{yy} + \varepsilon_{zz}) = -2a_{\varepsilon} \left( 1 - \frac{C_{12}}{C_{11}} \right) \varepsilon \]

\[ Q_{\varepsilon} = -\frac{b}{2} (\varepsilon_{xx} + \varepsilon_{yy} - 2\varepsilon_{zz}) = -b \left( 1 + 2 \frac{C_{12}}{C_{11}} \right) \varepsilon \]

\[ a = a_{\varepsilon} - a_{\sigma} \quad \text{hydrostatic potential} \]

\[ b \quad \text{shear potential} \]

\[ E_{HH}(k) = -P_{\varepsilon} - Q_{\varepsilon} - \frac{\hbar^2}{2m_0} \left[ (\gamma_1 + \gamma_2)k_z^2 + (\gamma_1 - 2\gamma_2)k_z^2 \right] \]

\[ E_{LH}(k) = -P_{\varepsilon} + Q_{\varepsilon} - \frac{\hbar^2}{2m_0} \left[ (\gamma_1 - \gamma_2)k_z^2 + (\gamma_1 + 2\gamma_2)k_z^2 \right] \]

\[ m_{hh} = \frac{m_0}{\gamma_1 - 2\gamma_2} \quad m_{hh}' = \frac{m_0}{\gamma_1 + \gamma_2} \]

\[ m_{lh} = \frac{m_0}{\gamma_1 + 2\gamma_2} \quad m_{lh}' = \frac{m_0}{\gamma_1 - \gamma_2} \]
Use longitudinal effective mass to calculate the quantum well levels:

\[ m_{\text{lh}}^* = \frac{m_{\text{h}}}{\gamma_1 - 2\gamma_2} \quad \text{LH:} \quad m_{\text{lh}}^* = \frac{m_{\text{h}}}{\gamma_1 + 2\gamma_2} \]

Use transverse effective mass to calculate 2-d density of states, gain, etc.

\[ m_{\text{lh}}^t = \frac{m_{\text{h}}}{\gamma_1 + \gamma_2} \quad \text{LH:} \quad m_{\text{lh}}^t = \frac{m_{\text{h}}}{\gamma_1 - \gamma_2} \]