ELEC-3140 Semiconductor physics — Nov 30, 2021

Exercise 8: Optical properties

1. A germanium wafer is doped with donors so that the carrier concentration is $n = 1\cdot 10^{16}\,\mathrm{cm}^{-3}$. Then, the wafer is illuminated so that electron-hole pairs are generated. Let this "surplus" carrier concentration be $1\cdot 10^{15}\,\mathrm{cm}^{-3}$. Calculate the quasi-Fermi levels in relation to the Fermi level of an undoped germanium wafer and compare the electron quasi-Fermi level position to the Fermi level of the doped material without illumination (for germanium $n_i = 2.33\cdot 10^{13}\,\mathrm{cm}^{-3}$).

2. A 1.05 μm thick $Ga_xIn_{1-x}As$ layer is grown on top of InP. The transmission T through the sample is measured at different wavelengths. Transmission data does not include reflections (i.e., we can neglect the reflections). At a wavelength of 1.60 μm, $T = 0.28$ and at 1.65 μm $T = 0.53$. Based on the data calculate the energy gap and the corresponding wavelength of the GaInAs layer.

3. Starting from Maxwell's equations show that a) the refractive index of a semiconductor $n = n_{re} + i\,n_{im}$ can be written as

$$n^2 = \left(n_{re} + i\,n_{im}\right)^2 = \varepsilon_r + i\frac{\sigma}{\varepsilon_0\,\omega}$$

and b) the absorption coefficient as

$$\alpha = 2\frac{\omega}{c}n_{im} \quad .$$

4. Figure shows a photoluminescence spectrum measured from GaAs. a) Estimate the band-gap energy of GaAs at the measurement temperature. b) There are transitions originating from an acceptor impurity state caused by carbon atoms. Calculate the ionisation energy of the acceptor state. c) Estimate the energy level of the donor state participating in transition DA.