Answer on Question #51558, Physics, Solid State Physics

Calculate the intrinsic carrier concentration for GaAs at $T = 300K$, given that $m_h = 0.56m_e$; $m_c = 0.068m_e$; $E_g = 1.42eV$.

Solution

The intrinsic carrier concentration for GaAs is given by Eq.(1)

$$n_i = \sqrt{N_c N_h}\exp\left(-\frac{E_g}{2kT}\right) \quad (1)$$

where $k = 1.38\cdot 10^{-23} J/K$ is the Boltzmann constant; $T = 300K$ is the temperature.

Effective density of states for electrons in the conduction band and for holes in the valence band are given by Eq.(2)-(3).

$$N_h = \frac{2\left(2\cdot\pi\cdot m_h\cdot k\cdot T\right)^{3/2}}{h^3} = \frac{2\left(2\cdot\pi\cdot 0.56\cdot 9{,}1\cdot 10^{-31}kg\cdot 1{,}38\cdot 10^{-23}J/K\cdot 300K\right)^{3/2}}{\left(6{,}62\cdot 10^{-34}\right)^3} = 1.05\cdot 10^{25}m^{-3} \quad (2)$$

$$N_c = \frac{2\left(2\cdot\pi\cdot m_c\cdot k\cdot T\right)^{3/2}}{h^3} = \frac{2\left(2\cdot\pi\cdot 0{,}068\cdot 9{,}1\cdot 10^{-31}\cdot 1{,}38\cdot 10^{23}T\right)^{3/2}}{\left(6{,}62\cdot 10^{34}\right)^{-3}} = 4.45\cdot 10^{23}m^{-3} \quad (3)$$

where $h = 6{,}62\cdot 10^{-34} J\cdot s$ is the Planck constant.

So, the intrinsic concentration

$$n_i = 10^{23}\sqrt{1.05\cdot 100\cdot 4.45}\exp\left(-\frac{1{,}42}{2\cdot 8{,}625\cdot 10^{-5}\cdot 300}\right) \approx 2.6\cdot 10^{12}m^{-3}\ . \quad (4)$$

Answer: $n_i \approx 2.6\cdot 10^{12}m^{-3}$