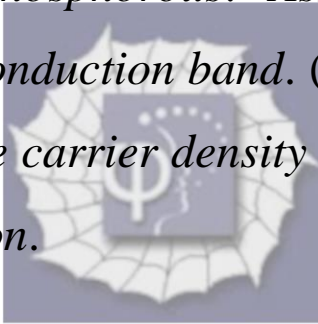


808.

Problem 53.35 (RHK)

Pure silicon at 300 K has an electron density in the conduction band of $1.5 \times 10^{16} \text{ m}^{-3}$ and an equal density of holes in the valence band. Suppose that one of every 1.0×10^{17} silicon atoms is replaced by a phosphorous atom. (a) We have to find the charge carrier density due to addition of phosphorous. Assume that all donor electrons are in conduction band. (b) We have to find the ratio of the charge carrier density in the doped silicon to that for pure silicon.



Solution:

(a)

We will calculate first the number density of silicon atoms before it is doped with phosphorous. It is given by

$$n_{\text{Si}} = \frac{N_A \rho_{\text{Si}}}{M_{\text{Si}}}.$$

We use the following physical data for silicon:

molar mass, $M_{\text{Si}} = 28.1 \text{ g mol}^{-1}$,

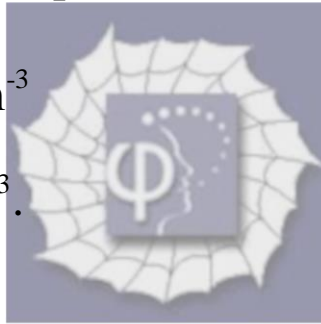
mass density of silicon, $\rho_{\text{Si}} = 2.33 \text{ g cm}^{-3}$.

We find

$$\begin{aligned} n_{\text{Si}} &= \frac{N_A \rho_{\text{Si}}}{M_{\text{Si}}} = \frac{6.02 \times 10^{23} \text{ mol}^{-1} \times 2.33 \times 10^3 \text{ kg m}^{-3}}{28.1 \times 10^{-3} \text{ kg mol}^{-1}} \\ &= 4.99 \times 10^{28} \text{ atoms per cubic meter.} \end{aligned}$$

It is given that silicon is doped with phosphorous by adding one phosphorous atom for every 1.0×10^{17} silicon atoms. Therefore, the number of phosphorous atoms per cubic meter in the doped silicon will be

$$\begin{aligned} n_{\text{P}} &= \frac{4.99 \times 10^{28}}{1.0 \times 10^7} \text{ m}^{-3} \\ &= 4.99 \times 10^{21} \text{ m}^{-3}. \end{aligned}$$



As each phosphorous atom contributes one electron to the conduction band, the charge carrier density in the doped silicon will be $4.99 \times 10^{21} \text{ m}^{-3}$.

(b)

The pure silicon at 300 K has an electron density in the conduction band of $1.5 \times 10^{16} \text{ m}^{-3}$ and an equal density of holes in the valence band. Therefore, the charge carrier density in pure silicon is

$$2 \times 1.5 \times 10^{16} \text{ m}^{-3} = 3.0 \times 1.5 \times 10^{16} \text{ m}^{-3}.$$

The ratio of the charge carrier density in the doped silicon to that for pure silicon will therefore be

$$\frac{4.99 \times 10^{21}}{3.0 \times 10^{16}} = 1.66 \times 10^5 .$$

