
Problem 2.14 How many phosphorus atoms must be added to decrease the resistivity of n-type silicon at room temperature from 1 Ω -cm to 0.1 Ω -cm. Make sure you include the doping dependence of the mobility. State your assumptions.

Solution Starting with a initial guess that the conductivity is due to electrons with a mobility of 1400 $\text{cm}^2/\text{V-s}$, the corresponding doping density corresponding to the initial resistivity of 1 Ω -cm equals:

$$N_d \cong n = \frac{1}{q m_h r} = \frac{1}{1.6 \times 10^{-19} \times 1400 \times 1} = 4.46 \times 10^{15} \text{ cm}^{-3}$$

The mobility corresponding to this doping density equals

$$m_h = m_{\min} + \frac{m_{\max} - m_{\min}}{1 + \left(\frac{N_d}{N_r}\right)^a} = 1274 \text{ cm}^2/\text{V-s}$$

Since the calculated mobility is not the same as the initial guess, this process must be repeated until the assumed mobility is the same as the mobility corresponding to the calculated doping density, yielding:

$$N_{d, \text{initial}} = 4.94 \times 10^{15} \text{ cm}^{-3} \text{ and } m_h = 1265 \text{ cm}^2/\text{V-s}$$

Repeating this procedure for a resistivity of 0.1 Ω -cm one find the final doping density to be

$$N_{d, \text{final}} = 8.08 \times 10^{16} \text{ cm}^{-3} \text{ and } m_h = 772 \text{ cm}^2/\text{V-s}$$

The added density of phosphorous atoms therefore equals

$$N_{d, \text{added}} = 8.08 \times 10^{16} - 4.94 \times 10^{15} = 7.59 \times 10^{16} \text{ cm}^{-3}$$
