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Problems for *Physik der Materie III*

Due by July 3, 2019

Series 10: Intrinsic and doped semiconductors

10.1 Band structure of an intrinsic semiconductor

Figure 1 shows the schematic density of states $D(E)$ of a hypothetical intrinsic semiconductor.

(a) Determine the position of the Fermi level E_F relative to the edges of the conduction (E_C) and valence (E_V) bands in units of eV.
A factor of two for the spin degeneracy is already included in $D(E)$. (Hint: Approximate the Fermi-Dirac distribution.)

(b) Calculate the carrier concentration n in the conduction band at ambient temperature ($T = 300$ K).

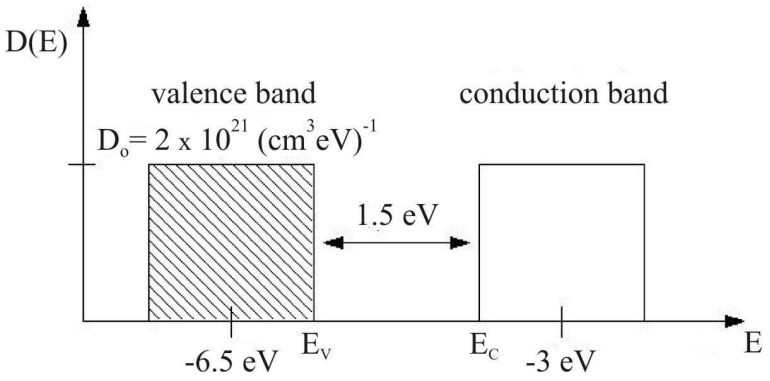

Figure 1: Schematic density of states

10.2 Doping concentration of semiconductors

For the parabolic approximation of the density of states near the band maxima and minima, the charge carrier concentration of intrinsic semiconductors depends on the temperature, the effective masses, and the energy gap. Using the corresponding general expression for the charge carrier concentration, determine the concentration N_D of an arsenic donor that leads to a 10^4 times larger conductivity compared to the intrinsic conductivity of silicon at room temperature (T = 300 K). Crystalline silicon has a band gap E_g of 1.14 eV at T = 300 K. The effective masses of the

electrons and holes contributing to the intrinsic conductivity are assumed to be $m_n^* \approx 0.2m_e$ and $m_p^* \approx 0.3m_e$, respectively. The mobilities of electrons and holes are approximated to be identical.

10.3 Ionization energies of donors and acceptors

Electrically active impurities in a semiconductor raise the concentration of mobile charge carriers by donating electrons to the conduction band or by accepting them from the valence band. The binding energies of the carriers to the impurities can be estimated by treating the donor (d) or acceptor (a) in a semiconductor lattice as a hydrogen atom embedded in a dielectric medium.

(a) Briefly describe the changes that have to be made in the expressions for the Bohr radius and the ionization energy compared to the original hydrogen atom model.

(b) Using the hydrogen-like model of dopants in semiconductors calculate the Bohr radii in Å and the ionization energies (E_d and E_a) in eV for gallium arsenide ($m_n^* \approx 0.066\, m_e$, $m_{p,l}^* \approx 0.082\, m_e$ (light holes), $m_{p,h}^* \approx 0.5\, m_e$ (heavy holes) and $\epsilon_r = 13.1$).