CMP - Sheet 9 21.06.14

9.1 p-doped semiconductor

- energy gap E_g
- acceptor concentration $n_A = 5 \times 10^{23}\ m^{-3}$
- acceptor level $E_a = 0.15\, E_g + E_v$
- temperature $T = 0.08\, E_g / k_B$
- Fermi energy $E_F = 5 k_B T + E_v$
- electrons: $m_n^* = 0.3\, m_e$
- holes: $m_h^* = m_e$

(a) concentration n_A^- of ionized acceptor atoms

$g_A = 1$ (weighing factor) — not ionized: $\circ$, ionized: $-$

split n_A into $n_A = n_A^\circ + n_A^-$

with Fermi-Dirac: probability that ground state is occupied (i.e. no ionization):

$$\frac{n_A^\circ}{n_A} = \left[g_A e^{(E_F - E_A)/k_B T} + 1 \right]^{-1}$$

↑ considers degeneration of impurity level

$$\Rightarrow n_A^- = n_A - n_A^\circ = n_A \left(1 - \frac{n_A^\circ}{n_A} \right)$$

$$= n_A \left(\frac{1}{e^{(E_F - E_A)/k_B T} + 1} \right)$$

and $$\frac{E_F - E_A}{k_B T} = \frac{5 k_B T + E_v - 0.15 E_g - E_v}{k_B T}$$

$$= \frac{5 \cdot 0.08\, E_g - 0.15\, E_g}{0.08\, E_g} = \frac{25}{8}$$

$$\Rightarrow \underline{n_A^- = 2.1 \times 10^{22}\ m^{-3}}$$

(b) Ladungsneutralität: $n + n_A^- = p + n_D^+$

p-doped $\Rightarrow n_A^- \gg n$, $n_A \gg n_D \approx 0$

$\Rightarrow n_A^- \approx p = 2.1 \times 10^{22}\ m^{-3}$

und $n \cdot p = n_i^2 \Rightarrow n = \frac{n_i^2}{n_A^-}$

$$\rightarrow n = \frac{4}{n_A^-}\left(\frac{k_B T}{2\pi\hbar^2}\right)^3 (m_n^* m_p^*)^{3/2}\, e^{-E_g/k_B T} \qquad \left| E_g = \frac{1}{0.08} k_B T \right.$$

$$= \ldots \qquad e^{-\frac{1}{0.08}}$$

$$= 9.7 \times 10^4\ m^{-3}$$

↑ Temp. aus (c)

(c) $$p = 2\left(\frac{m_p^* k_B T}{2\pi\hbar^2}\right)^{3/2} e^{\frac{E_V - E_F}{k_B T}} \approx n_A^- \qquad \left| E_F = E_V + 5 k_B T \right.$$

$$= 2\left(\frac{m_p^* k_B T}{2\pi\hbar^2}\right)^{3/2} e^{-5}$$

$$\Rightarrow \frac{m_p^* k_B T}{2\pi\hbar^2} = \left(n_A^- e^5\right)^{2/3} \Rightarrow$$

$$\Rightarrow T = \frac{2\pi\hbar^2}{m_p^* k_B}\left(n_A^- e^5\right)^{2/3}$$

$$= 118.5\ K$$

3.2 Unknown Semiconductor

-> determine sign, concentration and mobility of the charge carriers in a semiconductor

Hall-Messung: $R_H = \frac{p\mu_p^2 - n\mu_n^2}{e(p\mu_p + n\mu_n)^2}$

Vorzeichen ~ Ladung der Majoritäten

Dominiert eine Sorte => sofort Konzentration

↳ Hall-Konstante: $A_H = \frac{U_H d}{I B_z}$

Mobilität: $\mu = \frac{\sigma}{en}$ (σ: messen, n: dominant)