Chapter 4

1. $\sigma = n_i q(\mu_n + \mu_p)$

$= 10^{10} \times 1.6\times10^{-19} \times 2\times10^{3}$

$= 3.2\times10^{-6}\ \frac{C}{Vs\,cm} = 3.2\times10^{-6}\ \Omega^{-1}\,cm^{-1}$

$\rho = \frac{1}{\sigma} = 3.125\times10^{5}\ \Omega\cdot cm$

2. 载流子为掺杂的As带来的电子 $n_i = 1\times10^{10}\ cm^{-3}$ $\mu_n = 1450\ cm^2/(V\cdot s)$

$\frac{1}{\rho} = n_0 e \mu_n \Rightarrow n_0 = \frac{1}{\rho\, 1.6\times10^{-19}\times 1450} = 4.3\times10^{14} \sim 4.3\times10^{15}$

$p_0 = \frac{n_i^2}{n_0} = 2.32\times10^{4} \sim 2.32\times10^{5}$

3. $\mu = \frac{q\tau}{m^*} \Rightarrow \tau_n = \frac{\mu_n m_n^*}{q} = \frac{8000\times0.06\times9.1\times10^{-31}}{1.6\times10^{-19}} \times10^{-4}$

$= 2.73\times10^{-13}\ s$

$\tau_p = \frac{\mu_p m_p^*}{q} = \frac{400\times0.5\times9.1\times10^{-31}}{1.6\times10^{-19}} \times10^{-4}$

$= 1.1375\times10^{-13}\ s$

4. $\frac{4 g_A N_A}{N_V} e^{-\frac{E_A-E_V}{k_0T}} = \frac{4\times4\times10^{16}}{1.1\times10^{19}} e^{\left(-\frac{50\times10^{-3}\times1.6\times10^{-19}}{1.38\times10^{-23}\times200}\right)}$

$= 0.264 < 1$

$\Rightarrow$ 中间电离区

$p = \frac{N_V}{2g_A} e^{-\frac{E_A-E_V}{k_0T}} \left(\sqrt{1+\frac{4g_AN_A}{N_V}e^{\frac{E_A-E_V}{k_0T}}}-1\right) \approx 9\times10^{15}\ cm^{-3}$

$\mu \propto T^{-\frac{3}{2}}$

$\Rightarrow \mu(200k) = \mu(300k)\cdot\left(\frac{200}{300}\right)^{-\frac{3}{2}}$

$= 918.56\ cm^2/Vs$

$\Rightarrow \rho = \frac{1}{pe\mu} = 0.756\ \Omega\cdot cm$

5. 对硅的价带，有

$g_{轻}(E) = \frac{L^3}{2\pi^2\hbar^3}\sqrt{2(E_V-E)}\cdot(m_{pl})^{\frac{3}{2}}$

$g_{重}(E) = \frac{L^3}{2\pi^2\hbar^3}\sqrt{2(E_V-E)}\cdot(m_{ph})^{\frac{3}{2}}$

$\mu_l = e\tau_p m_{pl}^{*-1}$ $\mu_h = e\tau_p m_{ph}^{*-1}$

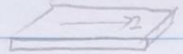
$\frac{g_{轻}}{g_{重}} = \left(\frac{m_{pl}^*}{m_{ph}^*}\right)^{\frac{3}{2}}$

$\Rightarrow \mu_p = \frac{m_{pl}^{*\frac{3}{2}}}{m_{ph}^{*\frac{3}{2}}+m_{pl}^{*\frac{3}{2}}}\times e\tau_p m_{pl}^{*-1} + \frac{m_{ph}^{*\frac{3}{2}}}{m_{ph}^{*\frac{3}{2}}+m_{pl}^{*\frac{3}{2}}}\times e\tau_p m_{ph}^{*-1}$

$= e\tau_p\cdot\frac{m_{pl}^{*\frac{1}{2}}+m_{ph}^{*\frac{1}{2}}}{m_{ph}^{*\frac{3}{2}}+m_{pl}^{*\frac{3}{2}}}\times10^{4} = 661\ cm^2/Vs$

$$m_c^* = \frac{m_{ph}^{*\frac{3}{2}} + m_{pl}^{*\frac{3}{2}}}{m_{ph}^{*\frac{1}{2}} + m_{pl}^{*\frac{1}{2}}} \approx 0.4\, m_0$$

6.



$S = 20 \times 20 = 400 \ nm^2$

$l = 100 \ nm$

$$\sigma = n\mu \cdot e = 10^{16} \times 1000 \times 1.6 \times 10^{-19}$$
$$= 1.6 \ \Omega^{-1} cm^{-1}$$

$$R = \frac{l}{\sigma S} = \frac{100 \ nm}{1.6 \ \Omega^{-1} cm^{-1} \times 400 \ nm^2}$$

$$= \frac{100}{1.6 \times 400} \cdot \frac{10^{-9}}{10^{-9} \times 10^{-9} / 10^{-2}} = 1562.5 \ k\Omega$$

$$I = \frac{U}{R} = \frac{3 \ V}{1562.5 k\Omega} = 1.92 \ \mu A$$

7. $\sigma = ne\mu_n + pe\mu_p$

$$= ne\mu_n + \frac{n_i^2}{n} e\mu_p \geq 2n_i e\sqrt{\mu_n \mu_p}$$

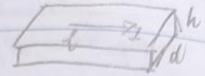
等号当且仅当 $ne\mu_n = \frac{n_i^2}{n} e\mu_p$

即 $n = n_i \sqrt{\mu_p / \mu_n}$ 时成立

此时 $p = \frac{n_i^2}{n} = n_i \sqrt{\mu_n / \mu_p}$

$\sigma = 2n_i e\sqrt{\mu_n \mu_p}$

8. 上正下负 载流子为空穴



$$\begin{cases} I = nqv S \\ Bvq = Eq = \frac{U}{d} q \end{cases}$$

$$\Rightarrow I = nq \frac{U}{dB} \cdot hd = nq \frac{U}{B} h$$

$$\Rightarrow n = \frac{BI}{qUh}$$

$$= \frac{20 \times 10^{-4} \times 1 \times 10^{-3}}{1.6 \times 10^{-19} \times 3.2 \times 10^{-3} \times 100 \times 10^{-6}}$$

$$= 3.90625 \times 10^{19} \ m^{-3} = 3.90625 \times 10^{13} \ cm^{-3}$$

$$\frac{U}{I} = R = \frac{l}{\sigma S} = \frac{l}{\sigma hd} = \frac{2.5}{\sigma h}$$

$$\Rightarrow \sigma = \frac{2.5 I}{U h} = \frac{2.5 \times 10^{-3}}{2 \times 100 \times 10^{-6}} = 12.5 \ \Omega^{-1} m^{-1}$$
$$= 0.125 \ \Omega^{-1} cm^{-1}$$

$\sigma = nq\mu$

$$\Rightarrow \mu = \frac{\sigma}{nq} = \frac{0.125 \ \Omega^{-1} cm^{-1}}{3.90625 \times 10^{13} cm^{-3} \times 1.6 \times 10^{-19} C}$$

$$= 20000 \ cm^2 / Vs$$

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