①

a) $\bullet \overset{-\gamma}{—} \underset{-u}{\bullet} \overset{-\gamma}{—} \bullet$ $E_\bullet(k) = -u - (-\gamma)e^{ika} - (-\gamma)e^{-ika} =$

$= -u + 2\gamma\cos ka$

$\circ \overset{\gamma}{—} \underset{u}{\circ} \overset{\gamma}{—} \circ$ $E_\circ(k) = u - \gamma e^{ika} - \gamma e^{-ika} =$

$= u - 2\gamma\cos ka$ 1/4+

b) $-u\psi_{\bullet m} - (-\gamma)\psi_{\bullet m+1} - (-\gamma)\psi_{\bullet m-1} - \gamma'\psi_{\circ m-1} - (-\gamma')\psi_{\circ m+1} = E\psi_{\bullet m}$

$u\psi_{\circ m} - \gamma\psi_{\circ m+1} - \gamma\psi_{\circ m-1} - \gamma'\psi_{\bullet m+1} - (-\gamma')\psi_{\bullet m-1} = E\psi_{\circ m}$

nastavek: $\psi_{\bullet m} = \psi_\bullet e^{ikma}$

$\psi_{\circ m} = \psi_\circ e^{ikma}$

$-u\psi_\bullet + \gamma\psi_\bullet e^{ika} + \gamma\psi_\bullet e^{-ika} - \gamma'\psi_\circ e^{-ika} + \gamma'\psi_\circ e^{ika} = E\psi_\bullet$

$u\psi_\circ - \gamma\psi_\circ e^{ika} - \gamma\psi_\circ e^{-ika} - \gamma'\psi_\bullet e^{ika} + \gamma'\psi_\bullet e^{-ika} = E\psi_\circ$

$$\det\begin{bmatrix} -u + 2\gamma\cos ka - E, & 2i\gamma'\sin ka \\ -2i\gamma'\sin ka, & u - 2\gamma\cos ka - E \end{bmatrix} = 0$$

$$E^2 - (-u + 2\gamma\cos ka)^2 - (2\gamma'\sin ka)^2 = 0$$

$$E = \pm\sqrt{(-u + 2\gamma\cos ka)^2 + (2\gamma'\sin ka)^2}\ ; \ \gamma = \gamma'$$ 1/4+

c) $E = 0$ za $\sin ka = 0$ & $\cos ka = \frac{u}{2\gamma}$

① $k = 0 \rightarrow u = 2\gamma$

② $k = \frac{\pi}{a} \rightarrow u = -2\gamma$ +

d) $u = 2\gamma \Rightarrow E_\pm = \pm 2\gamma\sqrt{(-1+\cos ka)^2 + \sin^2 ka} \doteq \pm 2\gamma a|k|$

$E > 0$: $g(E) = \frac{dN}{L\,dE} = \frac{dN}{L\,d|k|}\frac{d|k|}{dE_+} = \frac{1}{L}2\cdot 2\frac{L}{2\pi}\frac{1}{2\gamma a} = \frac{1}{\pi\gamma a}$

$g(-E) = g(E)$ (vsakemu stanju $E+$ pripada natanko eno stanje z energijo $E_- = -E+$) 1/4

② a) $T = 1K$

$$\left[\frac{\varepsilon_c - \mu}{k_B T} = \frac{\varepsilon_c - \varepsilon_d}{2 k_B T} - \ln\sqrt{\frac{N_d}{2N_c}} = 9.9 \gg 1 \right.$$
nedegeneriran polprevodnik]

vaje $$\begin{cases} \frac{8N_d}{N_c} e^{\beta(\varepsilon_c - \varepsilon_d)} = 6.0 \times 10^{11} \gg 1 \\ n_c = \sqrt{\frac{N_d N_c}{2}} e^{-\beta \frac{\varepsilon_c - \varepsilon_d}{2}} = \underline{2.6 \times 10^{10} cm^{-3}} \end{cases}$$

1/4 +

$T = 300K$

$$\left[\frac{\varepsilon_c - \mu}{k_B T} = -\ln \frac{N_d}{N_c} = 5.6 \gg 1 \right.$$
nedegeneriran polprevodnik]

vaje $$\begin{cases} \frac{8N_d}{N_c} e^{\beta(\varepsilon_c - \varepsilon_d)} = 0.033 \ll 1 \\ n_c = N_d = \underline{10^{16} cm^{-3}} \end{cases}$$

1/4 +

$$p_v \doteq \frac{n_i^2}{n_c} = \frac{N_c P_v e^{-\beta(\varepsilon_c - \varepsilon_v)}}{n_c} = 7.2 \times 10^9 cm^{-3} \ll n_c \checkmark$$

vrzeli v valenčnem pasu sem upravičeno zanemaril

b) $n_c = p_d$

$$\int g_c(\varepsilon) F(\varepsilon) d\varepsilon = \frac{N_d}{1 + 2e^{-\beta(\varepsilon_d - \mu)}} \quad ; \mu = \varepsilon_c,$$ zato je polprevodnik degeneriran!

$$\int_{\varepsilon_c}^{\infty} \frac{\sqrt{2(m_c^*)^3}}{\pi^2 \hbar^3} \sqrt{\varepsilon - \varepsilon_c} \frac{1}{e^{\beta(\varepsilon - \varepsilon_c)} + 1} d\varepsilon = \frac{N_d}{1 + 2e^{-\beta(\varepsilon_d - \varepsilon_c)}}$$

$$\int_0^{\infty} \frac{\sqrt{2(m_c^*)^3}}{\pi^2 \hbar^3} \beta^{-3/2} \frac{\sqrt{u}\, du}{e^u + 1} = \frac{N_d}{1 + 2e^{+\beta(\varepsilon_c - \varepsilon_d)}}$$

1/4 +

$$N_d = \frac{\sqrt{2(m_c^* k_B T)^3}}{\pi^2 \hbar^3} \left(1 + 2e^{\beta(\varepsilon_c - \varepsilon_d)}\right) \int_0^{\infty} \frac{\sqrt{u}\, du}{e^u + 1} = \underline{6.3 \times 10^{18} cm^{-3}}$$

$$N_d = \frac{2}{\sqrt{\pi}} \int_0^{\infty} \frac{\sqrt{u}\, du}{e^u + 1} N_c \left(1 + 2e^{\beta(\varepsilon_c - \varepsilon_d)}\right)$$