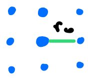
Trdna snov

Madelungova konstanta (α_i)



$$W_e = -\frac{e_0^2}{4\pi\varepsilon_0 r_0}\alpha_i$$

$$W_e = W_i + W_a + W_{vez}$$

Blochov izrek

Če imamo periodičen potencial, potem ψ zapišemo kot neki val krat u, u je periodičen

$$\psi(\vec r) = e^{i\vec k\vec r}u_k(\vec r) = \psi(\vec r + \vec R) \qquad u_k(\vec r) = u_k(\vec r + \vec R)$$

Sobna temperatura $k_BT = \frac{1}{40}eU$

Gibljivost $\beta = \frac{e\tau}{m}$

$$\frac{d\langle\vec p\rangle}{dt} = -e\vec E - e\langle\vec v\rangle\times\vec B - \frac{\langle\vec p\rangle}{\tau}$$

$$W_F = \frac{mv_F^2}{2} = \frac{\hbar^2k^2}{2m}$$

Povprečna prosta pot $L = \beta v_F$

$$\omega_c = \frac{eB}{m}$$

$\langle v\rangle = -\beta E = -\left(\frac{e\tau}{m}\right)E$

$j = en\langle v\rangle$

$\langle p\rangle = m\langle v\rangle$

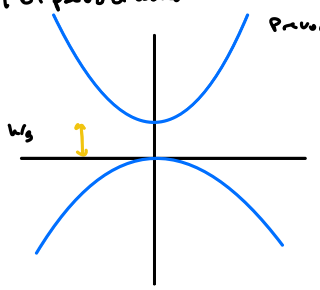
$j = \sigma E$

$R = \zeta\frac{l}{S} \qquad \zeta = \frac{1}{\sigma}$

Spec. el. prevodnost $\sigma = e\beta n = \frac{e^2n\tau}{m}$

$$N = 2\frac{V_F}{V_1} = 2\frac{4\pi k_F^3/3}{\left(\frac{2\pi}{L}\right)^3} = \frac{k_F^3L^3}{3\pi^2} \qquad n = \frac{N}{L^3} = \frac{k_F^3}{3\pi^2}$$

- **Polprevodniki**



$$g(E) = A_eV\sqrt{E} \qquad A_e = \frac{1}{3\pi^2}\left(\frac{2m}{\hbar^2}\right)^{3/2}\frac{3}{2}$$

$$f(E) = \frac{1}{1+\exp(\beta(E-\mu))} \qquad \beta = \frac{1}{k_BT} \qquad N = N_e + N_v$$

$$N_e = \int_{W_g}^{\infty} f(E)\,g_e(E)\,dE \qquad g(E) = \frac{G(E)}{V} = A_p\sqrt{E}$$

$$N_v = \int_{-\infty}^{0}(1-f(E))\,g_v(E)\,dE \qquad g(E) = A_v\sqrt{E}$$

$$g_p = \frac{1}{2\pi^2}\left(\frac{2m_e}{\hbar^2}\right)^{3/2}\sqrt{W-W_g} = A_p\sqrt{W-W_g}$$

$$g_v = \frac{1}{2\pi^2}\left(\frac{2m_v}{\hbar^2}\right)^{3/2}\sqrt{-W} = A_v\sqrt{-W}$$

$$W = W_g + \frac{(\hbar k)^2}{2m_e}$$

$$E_F = W_g + \frac{3}{4}k_BT\ln\left(\frac{m_v}{m_e}\right)$$

$T>0$: $n_p = \frac{\sqrt{\pi}}{2}A_p(k_BT)^{3/2}e^{-(E_g-\mu)\beta}$

$n_v = \frac{\sqrt{\pi}}{2}A_v(k_BT)^{3/2}e^{-\mu\beta}$

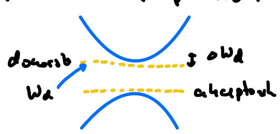
Ča $n_p = n_v \Rightarrow \mu = \frac{3}{4}k_BT\ln\frac{m_v}{m_p} + \frac{E_g}{2}$

$$n_pn_v = n_0^2e^{-\beta E_g} \qquad n_0 = \frac{1}{2\pi^2}\left(\frac{2m_vm_e}{\hbar}\right)^{3/4}\frac{\sqrt{\pi}}{2}\beta^{-3/2}$$

le v čistem polprev. $\rightarrow (n_p = n_v) = n_0e^{-\beta E_g/2}$

- **Dopirani polprevodniki**

tip -n (5 val. e^-)



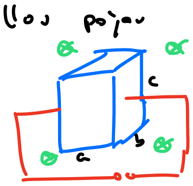
tip -p (3 val e^-)

$$\Delta E_d = \frac{e^4m_e^*}{32\pi^2(\varepsilon\varepsilon_0)^2\hbar^2}$$

vezavna energija donorskega e^-

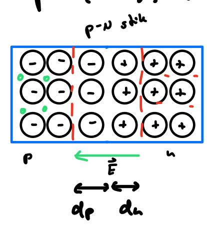
$$E_a = \frac{e^2m_v^*}{32\pi^2(\varepsilon\varepsilon_0)^2\hbar^2}$$

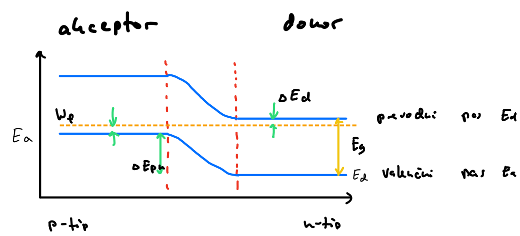
- **Hallov pojav**



$$U_H = \frac{IB}{b\cdot e\cdot n}$$

- **p-n stik**





V ravnovesju sta Fermijevi en. na obeh straneh enaki

$$\Delta E_{pn} = E_{Fn} - E_{Fp} \simeq E_d - E_a$$

$$n_{ep} = \left(\frac{m_e}{m_v}\right)^{3/4}n_0e^{-(E_g-E_{Fn})\beta} \simeq n_d$$

$$n_v = \left(\frac{m_v}{m_e}\right)^{3/4}n_0e^{-E_{Fp}\beta} \simeq n_a$$

$$E_{Fn} = E_g + k_BT\left(\ln\frac{n_d}{n_0} + \frac{3}{4}\ln\frac{m_v}{m_e}\right)$$

$$E_{Fp} = -k_BT\left(\ln\frac{n_a}{n_0} + \frac{3}{4}\ln\frac{m_e}{m_v}\right)$$

• El. polje na n strani $E_n(x) = \frac{e_0 n_d}{\varepsilon\varepsilon_0}(x+d_n)$

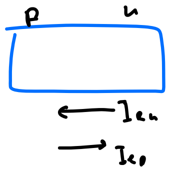
p strani $E_p(x) = \frac{e_0 n_a}{\varepsilon\varepsilon_0}(d_p - x)$

pogoj zveznosti $n_d d_n = n_a d_p$

$d_p \ll d_n$
$n_d \ll n_a$

širina plasti $\Delta E_{pn} = e_0 U_0 = \frac{e_0^2}{2\varepsilon\varepsilon_0} n_d \left(1 + \frac{n_d}{n_a}\right) d_n^2 \longrightarrow d_n = \sqrt{\frac{2\varepsilon\varepsilon_0 U_0}{e_0 n_d}} \approx d$

• El. tok v diodi



Če je še zun. napetost $d_n = \sqrt{\frac{2\varepsilon\varepsilon_0 (U_0 + U)}{e_0 n_d}}$

$U > 0$ prevodna smer

$U < 0$ zaporna smer

Brez zun. napetosti

$I_e = I_{en} - I_{ep} = 0$

$I_{en} = A \cdot n_0 \cdot e^{-\beta(\Delta E_{pn} + E_s - E_{Fn})}$

$I_{ep} = A\, n_0\, e^{-\beta(E_s - E_{Fp})}$

$I_{vn} = A'\, n_0\, e^{-\beta(\Delta E_{pn} + E_{Fp})}$

$I_{vp} = A'\, n_0\, e^{-\beta E_{Fn}}$

Zun. napetost

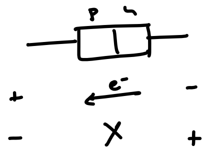
$\Delta E_{pn} \to \Delta E_{pn} - e_0 U$

$I_e' = I_{en}\left(e^{\beta e_0 U} - 1\right)$

$I_v' = I_{vn}\left(e^{\beta e_0 U} - 1\right)$

$I' = I_0\left(e^{\beta e_0 U} - 1\right)$

Upornik diode



Fotodioda

$I = I_0\left(e^{\beta e_0 U} - 1\right) - I_f$

$I_f = 2 e_0 \frac{\eta P_s}{h\nu}$

(z notranjim uporom $U \to U_B - IR$

Jedro

$^A_Z X_N$ radij jedra $r_j = r_0 \sqrt[3]{A_j}$ $r_0 \sim 1{,}25$ fm

$$E_v(A,Z) = -w_0 A + w_1 A^{2/3} + w_2 \frac{Z^2}{A^{1/3}} + w_3 \frac{(A-2Z)^2}{A} + w_4 \frac{\delta_{ZN}}{A^{3/4}} \qquad \delta_{ZN} = \begin{array}{c|cc} & N & Z \\ 1 & \text{lih} & \text{lih} \\ 0 & \text{lih} & \text{sod} \\ -1 & \text{sod} & \text{sod} \end{array}$$

$w_0 = 15{,}6$ MeV $\quad w_1 = 17{,}3$ MeV $\quad w_2 = 0{,}7$ MeV $\quad w_3 = 23{,}3$ MeV $\quad w_4 = 33{,}5$ MeV

Kriterij za stabilnost $E_{v,\,\text{reakt.}} \le E_{v,\,\text{prod.}}$