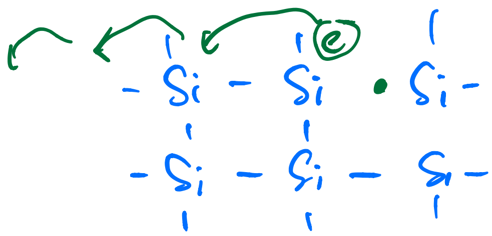
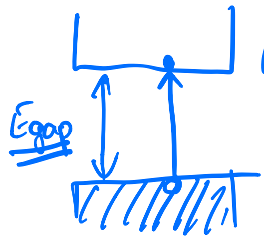
POLPREVODNIKI IN IZOLATORJI

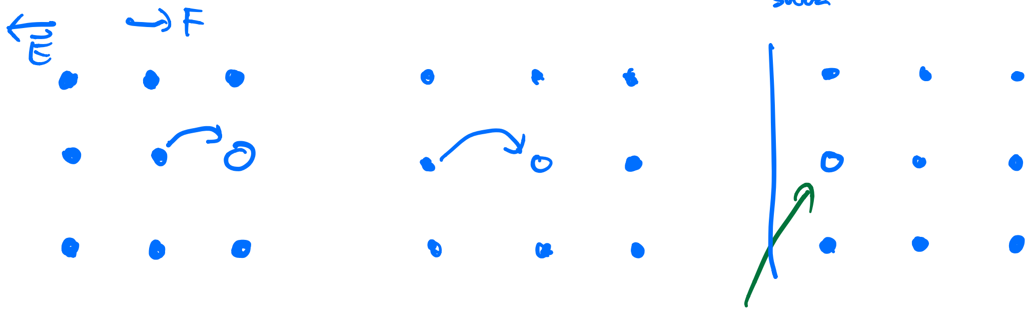
1) VRZEL





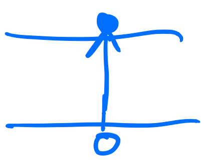
1) $T \neq 0$ $\lambda > E_{gap}$ fotoni

2) $T > 0$ termične vzbuditve $k_B T_{sobna} \sim \frac{1}{40}$ eV



vrzel, kvazidelec

$$\boxed{q = +e_0}$$



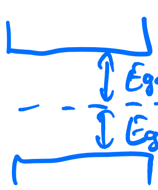
nastane par delec-vrzel

Rekombinacija: delec in vrzel izgineta, foton (svetloba), toplota.

$m_{\text{dinamična}} < 0$

Intrinzični polprevodnik (čist material).

2) GOSTOTA NOSILCEV NABOJA



$$f = \frac{1}{1+e^{(E-\mu)/k_BT}} = \begin{cases} e^{-(E-\mu)/k_BT} \\ 1-e^{(E-\mu)/k_BT} \end{cases}$$

$$\frac{1}{1+x} \approx 1-x$$

$$n_e = \frac{N_e}{V} = \int_{E_{dno}}^{\infty} g_p(E)\, f(E)\, dE = \underline{\quad}\ e^{-(E_{dno}-\mu)/k_BT} \qquad g_p \sim \sqrt{E - E_{dno}}$$

$$\int_0^\infty \sqrt{x}\, e^{-x/L}\, dx = \frac{\sqrt{\pi}}{2}(k_BT)^{3/2}$$

gostota prostih e^- v prevodnem pasu

$$n_v = \frac{N_v}{V} = \int_{-\infty}^{E_{vrh}} g_v(E)\, f(E)\, dE = \ldots\ e^{-(\mu - E_{vrh})/k_BT}$$

$$N_e = N_v \longrightarrow \mu = \frac{E_{dno} + E_{vrh}}{2}$$

$$n_e = n_v = \frac{1}{\sqrt{2}}\left(\frac{m_e k_B T}{\pi \hbar^2}\right)^{3/2} e^{-E_g/2k_BT}$$

$T = T_{sobna}$ $\quad E_g(Si) = 1{,}1\,eV$ $\quad n(Si) = 5 \cdot 10^{22}\,cm^{-3}$

$n_e = n_v = 1{,}08 \cdot 10^{10}\,cm^{-3}$

3) GIBLJIVOST

$v_e = \beta_e E \qquad v_v = \beta_v E$

$$j = \sigma E = (-e_0) n_e (v_e) + e_0 n_v v_v$$
$$= e_0 n_e \beta_e E + e_0 n_v \beta_v E$$
$$j = e_0 (n_e \beta_e + n_v \beta_v) E$$

$$\boxed{\sigma = e_0 (n_e \beta_e + n_v \beta_v)}$$

Si: $\quad \beta_e = 1500\,cm^2/Vs \qquad \beta_v = 450\,cm^2/Vs$

$n_e = n_v \qquad \sigma = e_0(\beta_e + \beta_v)\, c\, e^{-E_g/2k_BT}$

polprev: $T \nearrow \quad \sigma \nearrow$

kovine: $T \nearrow \quad \sigma \searrow$

4) DOPIRANI POLPREVODNIKI e^-

a) POLPREVODNIKI TIPA n, V. valentni atomi (As, P)

Si Si Si

Si As^+ Si
e^-

Si Si Si

$$E_I = \frac{m^* e_0^4}{(4\pi\varepsilon\varepsilon_0 \hbar^2)^2} \quad \frac{m^*}{\varepsilon^2} = \frac{1}{720} \rightarrow 0{,}02\,\mathrm{eV} \qquad r_H = \frac{4\pi\varepsilon\varepsilon_0 \hbar^2}{e_0^2 m^*} \propto \frac{\varepsilon}{m^*} = 60$$

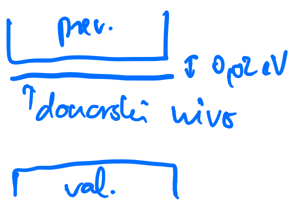
$$m_e \rightarrow m^* \qquad \frac{m^*}{m_e} = 0{,}2 \ (Si)$$

$$\frac{1}{4\pi\varepsilon_0 r} \rightarrow \frac{1}{4\pi\varepsilon\varepsilon_0 r}$$

ε dielektrična konstanta

$\varepsilon = 12$ (Si)

donorji



$$n_d \longrightarrow \sigma = e_0 n_d \beta_e$$

$$n_d = 10^{13} - 10^{18}\ \mathrm{cm}^{-3}$$

$$\rho(Si) = 5 \cdot 10^{22}\ \mathrm{cm}^{-3}$$

b) POLPREVODNIKI TIPA p

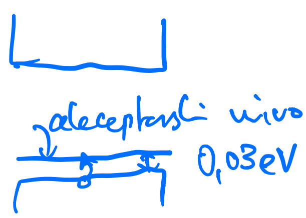
Si Si Si

Si B^- O^+ Si

Si Si Si

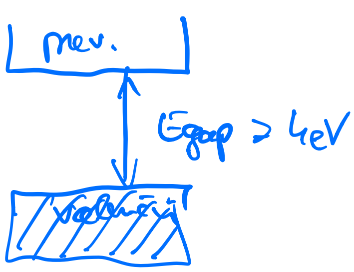
n_a akceptorji

$$\sigma = e_0 n_a \beta_v$$



5) IZOLATORJI

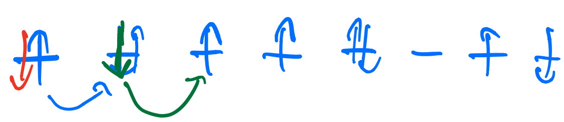
- Pasovni izolator

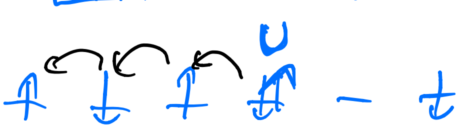


sodo št. elektronov na osnovno celico.

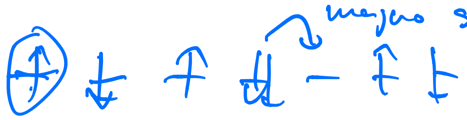
- Mottov izolator

pol zapoljen pas





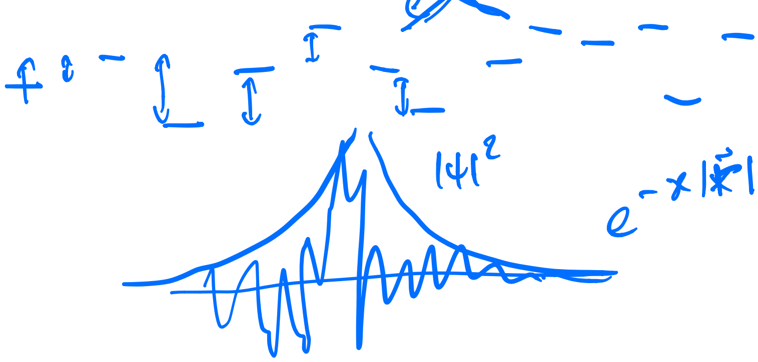
U zelo velik!



Mottov izolator. Cu_2O, V_2O_3, kuprati

Problem močno koreliranih elektronov. $\psi(\vec r_1, \vec r_2, \vec r_3, \dots, \vec r_{NA})$

- Andersonovi izolatorji $\cancel{e^{i\vec k\cdot\vec r}}$ $e^{i\vec k\cdot\vec r}$

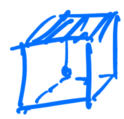


amorfni materiali, močno dopirani polprevodniki

SiO_2 $E_{gap} = 9eV$ HgON

6) TOPOLOŠKI IZOLATORJI

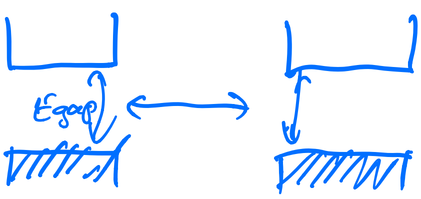
$E(k)$ $k \in$ recipročni prostor



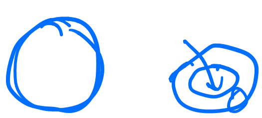
$E_n(k)$

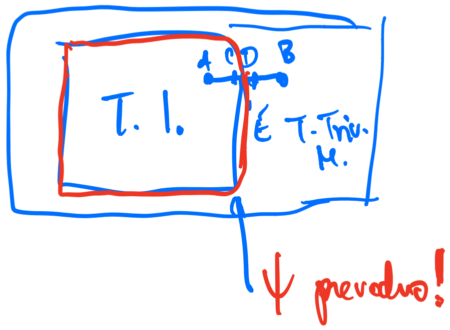
2D: $HgTe/CdTe$ (2007)

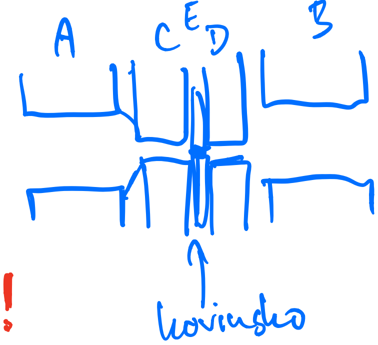
3D: Bi_2Se_3



Več različnih družin pasovne strukture. Razlike so topološke.







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