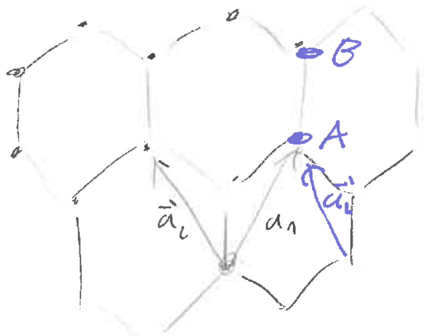
GRAFEN

0.77 mg / m²

4 kg

× el. lahko izbirem dli(?) prenosa

$c = 1/300\, c_0 \approx 10^6$ m/s

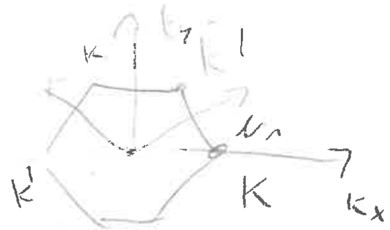


$\vec{a}_1 = a\left(1/2, \sqrt{3}/2\right)$

$\vec{a}_2 = a\left(-1/2, \sqrt{3}/2\right)$

$\vec{b}_1 = \frac{2\pi}{a}\left(1, \frac{1}{\sqrt{3}}\right)$

$\vec{b}_2 = \frac{2\pi}{a}\left(-1, \frac{1}{\sqrt{3}}\right)$



$\vec{K} = \frac{1}{3}(\vec{b}_1 - \vec{b}_2)$ $\qquad \vec{K}' = \frac{\vec{b}_2 - \vec{b}_1}{3}$

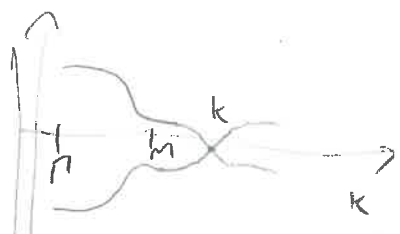
$$H = -t\left(\sum_{\vec{R}} |\psi^B_{\vec{R}-\vec{a}_1}\rangle\langle\psi^A_{\vec{R}}| + |\psi^B_{\vec{R}-\vec{a}_2}\rangle\langle\psi^A_{\vec{R}}| + |\psi^B_{\vec{R}}\rangle\langle\psi^A_{\vec{R}}|\right) + h.c.$$

$$|\psi^A_{\vec{k}}\rangle = \frac{1}{\sqrt{N}}\sum_{\vec{R}} e^{i\vec{k}\cdot\vec{R}}\, |\psi^A_{\vec{R}}\rangle \qquad ; \text{ isto za } B$$

$$|\psi_{\vec{k}}\rangle = \psi^A\, |\psi^A_{\vec{k}}\rangle + \psi^B\, |\psi^B_{\vec{k}}\rangle$$

$$H(\vec{k}) = \begin{bmatrix} 0 & e^*(k) \\ e(k) & 0 \end{bmatrix} \qquad H(k)\begin{pmatrix}\psi_A \\ \psi_B\end{pmatrix} = E\begin{pmatrix}\psi_A \\ \psi_B\end{pmatrix}$$

$$e(k) = -t\left(1 + e^{i\vec{k}\cdot\vec{a}_1} + e^{i\vec{k}\cdot\vec{a}_2}\right)$$



$$\det(H(k) - E) = 0 \qquad E^2 - |e|^2 = 0 \qquad E = \pm e$$

v bližini K, K'

Fermijeva energija nap.

$\vec{k} = \vec{K} + \vec{q}$

$\vec{K}\cdot\vec{a}_1 = \frac{2\pi}{3} \qquad \vec{K}\cdot\vec{a}_2 = -\frac{2\pi}{3}$ (1.)

$\vec{K}'\cdot\vec{a}_1 = \frac{-2\pi}{3}$
$\vec{K}'\cdot\vec{a}_2 = \frac{2\pi}{3}$

$1 + e^{i(\vec{K}+\vec{q})\cdot\vec{a}_1} + e^{i(\vec{K}+\vec{q})\cdot\vec{a}_2} = 1 + e^{i\frac{2\pi}{3}} e^{i\vec{q}\cdot\vec{a}_1} + e^{-i\frac{2\pi}{3}} e^{i\vec{q}\cdot\vec{a}_2}$

$= \left(1 + e^{i\frac{2\pi}{3}} + e^{-i\frac{2\pi}{3}} + e^{i\frac{2\pi}{3}}\, i\vec{q}\cdot\vec{a}_1 + e^{-i\frac{2\pi}{3}}\, i\vec{q}\cdot\vec{a}_2\right)$

$e^{-i\frac{2\pi}{3}} \qquad e^{i\frac{2\pi}{3}}$

$= i\left(\cos\frac{2\pi}{3}\, \vec{q}\cdot(\vec{a}_1+\vec{a}_2) \pm i \sin\frac{2\pi}{3}\, \vec{q}\cdot(\vec{a}_1-\vec{a}_2)\right)$

$= i\left(-\frac{1}{2}\left(\vec{q}\cdot(\vec{a}_1+\vec{a}_2)\right) \pm i\frac{\sqrt{3}}{2}\, \vec{q}\cdot(\vec{a}_1-\vec{a}_2)\right)$

$= i\left(-\frac{1\sqrt{3}}{2} q_y a + i\frac{\sqrt{3}}{2} q_x a\right) = -\frac{\sqrt{3}}{2}\left(q_x a + i q_y a\right)$

$e(k) = \frac{t a\sqrt{3}}{2}\left(q_x a + i q_y\right) \qquad E = \pm\frac{\sqrt{3}}{2} a t |\vec{q}| = \pm \hbar c^* q$

$\vec{q}$: posreda zgrin $\qquad c^* \sim 10^6\, m/s$

$\begin{bmatrix} & q_x - iq_y \\ q_x + iq_y & \end{bmatrix} = q_x \sigma_x + q_y \sigma_y \qquad \vec{q}\,\vec{\sigma} =$

$\hbar c^* (\hat{n}\vec{\sigma})\psi = E\psi \qquad n\cdot\vec{\sigma}$ zvirnost delca

V dolini k: $(\hbar c\, \vec{q}\,\vec{\sigma}\, \psi = E\psi)$

k': $\hbar c\, \vec{q}\cdot(-\vec{\sigma}^*)\psi = E\psi \qquad / e^{i\vec{q}\cdot\vec{r}}$

$\hbar c(\vec{p}\,\vec{\sigma})\psi_q(\vec{r}) = E\psi_q(\vec{r}) \qquad$ (lahko redefiniraš $q_y \to -q_y$)

TR: $H(K+\vec{q}) \longrightarrow H^*(-K-\vec{q}) = H(K'-\vec{q})^* =$ 2.)