

Carbon Materials [Le Huu]

Atomic shell: $1s^2 2s^2 2p^2$

Various pure element forms: fullerene, graphene, graphite, nanotube, diamond
 sp² hybridization
 trigonal planar

sp³ hybridization
 tetrahedral

- Graphene can be described by tight-binding model of π -orbital
 \rightarrow 2 inequivalent Dirac cones for nearest-neighbor tight-binding
 ▲ Introducing next-nearest-neighbor t' can break particle-hole symmetry. But still have 2 cones at half-filling.



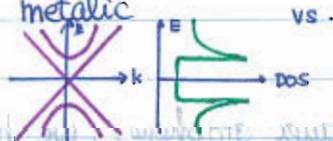
- Dirac node also survive when NN-bonds vary in strength:



- Nanotubes are obtained by rolling graphene sheet along certain direction. In Brillouin zone e^- are restricted to certain lines



- Thus there are 2 cases: metallic



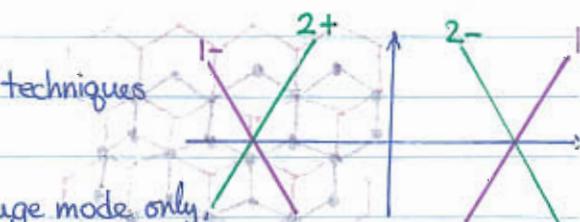
- Put in interaction, using previous techniques

$$\rightarrow H_{int} = e^2 \ln(R_s/R) \int dx f_{int}(x)$$

The interaction couples to total charge mode only.

3 neutral modes are NOT affected.

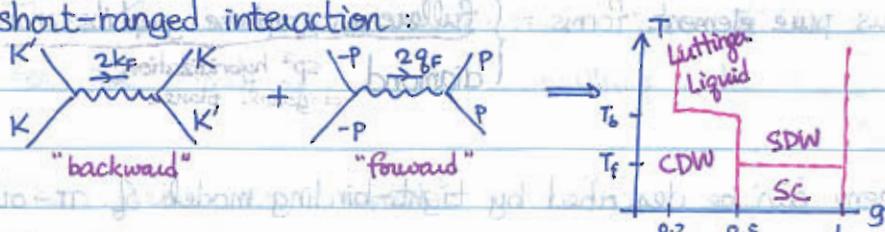
$$\text{For charged mode, } g = \left[1 + \frac{8e^2}{V_F \pi \hbar} \ln(R_s/R) \right]^{-1/2}$$



[Unit 5] Electron liquid

- From tunneling experiment, $g \approx 0.22$.

- In addition to long-ranged Coulomb, one can also put in short-ranged interaction:



- Now consider two-dimensional graphene.

- Klein paradox: perfect transmutation through classically forbidden region.

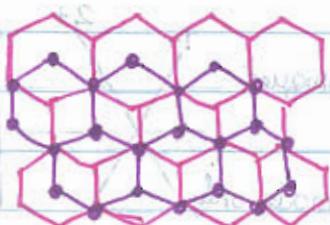
- In graphene, the "fine structure const." is $\alpha = \frac{e^2}{\epsilon_0 v_F}$.

The bare value is $\alpha \approx 1$. But RG predicts that α is marginally irrelevant.

- However, when $k_B T \gg \mu$ the system is still a non-Fermi liquid, where $\Sigma^1 \sim \alpha^2 T$.

- In real sample, graphene spatial density fluctuate rather strongly, possibly caused by graphene sheet bending.

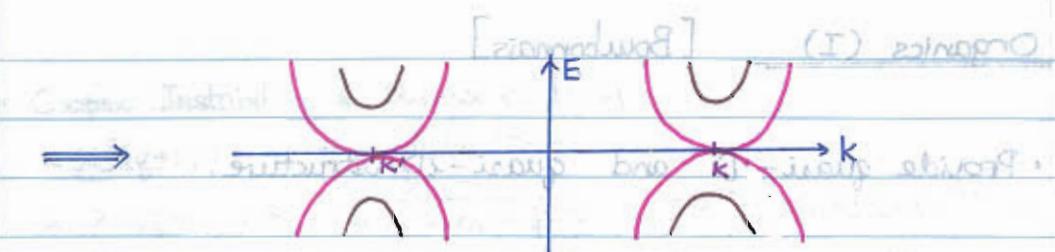
- For multi-layer graphene, we have specific stacking pattern:



$$\mathcal{H} = \begin{bmatrix} A & \tilde{B} & \tilde{A} & B \\ \tilde{B} & V\pi & V\pi & V\pi \\ \tilde{A} & V\pi & V\pi & V\pi \\ B & V\pi & V\pi & V\pi \end{bmatrix}$$

Lattice Heisenberg atom lattice F

$$= \left[\left(\frac{1}{2} \sin \left(\frac{\pi}{R} \right) - \frac{1}{2} \right) + i \right] F_{\text{atom frequency}}$$

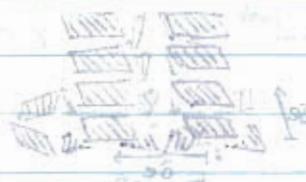


zurück zum zentralen Punkt geht die DNA um (rotiert) um einen Winkel α .



grundsätzlich für alle $\alpha = 0^\circ$ bzw. 180° und bei einem Winkel $\alpha \neq 0^\circ$ und $\alpha \neq 180^\circ$ müssen zwei der vier möglichen Zustände gleich sein.

Wegen dies trifft es also, dass zwei Blöcke mit



(CPV) $TTCG-TTCT$ abweichen.

$\alpha \neq \beta$ annehmen, ist dann

zweiterweise dass $\alpha = \beta$ ist.

II. in währenden Zuständen

unterschiedliche Positionen

Winkel $\beta = H$ zwischen einem β -Sektor und

$$(\rho_1 + \rho_2) \cdot \cos \beta = \rho_1 \cdot \cos \beta + \rho_2 \cdot \cos \beta + \rho_1 \cdot \sin \beta + \rho_2 \cdot \sin \beta = H$$

$$(H, \beta) \text{ ist } \frac{1}{\sqrt{H}} \sim (1, \beta^*) \quad \frac{1}{\sqrt{H}} \cdot T = (T, \beta) \xrightarrow{\beta^*}$$



Winkelwinkel mit einer Position in dem es

$$\sin^2 \beta = 0 \quad \Rightarrow \quad \sin \beta = 0 \quad \Rightarrow \quad \beta = 0^\circ$$