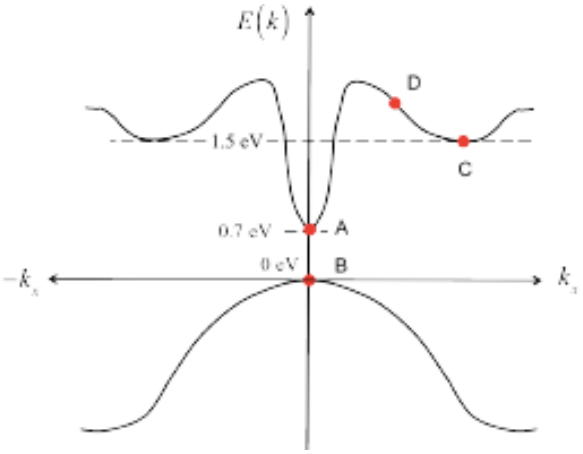
4TCH813U : Solid State Physics

TEST 2 (25/05/2020)

Important reminder: each answer should be justified

Part I – Just a little theory

Consider the $E(k)$ plot shown below. At the vicinity of points A, B, or C it is possible to show that dispersion relation $E(k)$ is similar to that of a free electron gas, provided that the mass of the electron is replaced by an effective mass m_{eff}.



1. How the concept of effective mass is related to the effective potential used in the nearly free electron model? What is the meaning of this relationship?

2. Express the free electron gas dispersion relation with the effective mass.
3. Show that the effective mass can be expressed as follows:

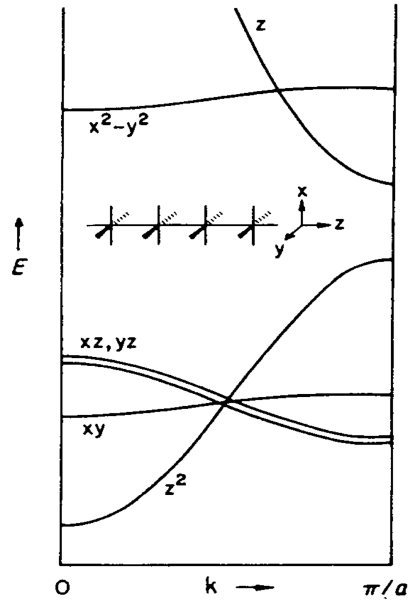
$$m_{eff} = \frac{\hbar^2}{d^2E(k)/dk^2}$$

where $\frac{d^2E(k)}{dk^2}$ is the local curvature of the dispersion relation at the vicinity of points A, B, or C.

4. Where is the effective mass for electrons the largest, point A or C?
5. Where is the mobility of electrons higher, point A or C?
6. What is the value of the band gap for this semi-conductor?
7. Compare the density of states (DOS) in energy at the vicinity of points A and C. Which one is larger?

Part II: A chemist view of dispersion relations of electrons in a solid

The figure below describe the dispersion relation of a stack of N Pt(II) square planar complexes aligned along z direction and equally spaced (with a the distance between two consecutive Pt).



1. Could you comment this figure, explaining why dispersion is higher for the d_{Z^2} band when compares to the $d_{X^2-Y^2}$ or d_{XY}.

2. Why d_{Z^2} band is going up while p_Z band is going down when k is going from the centre to the edge of the Brillouin zone.

3. How many electronic quantum states lies in the d_{Z^2} band from $k = \frac{-\pi}{a}$ to $\frac{+\pi}{a}$? Justify the answer.

4. A reduction of the Pt (II) complexes distance will give rise to a narrowing of the d_{Z^2} band? Or just the opposite? Will it be the same for the d_{XY} band?

Part III: few more questions

1. Electronic transport in a solid, induced by any applied electric field, is strongly related to the band structure. Could you explain why filled bands do not contribute to the electrical conductibility whereas partially filled bands contributes.

2. Show that, the highest the dispersion in a band the highest is the conductivity. Give both the chemist and physicist interpretations.

3. Looking at the dispersions curves below, could you say if the materials will behave as: a metal, a semi-conductor or an insulator?