4.7 EFFECTIVE MASS OF THE ELECTRON

Theoretically we take the mass of an electron in a solid, same as that of the mass of a free electron. Experimentally it is found that for some solids the mass is larger while for others it is slightly smaller than the free electrons mass.

This experimentally determined electron mass is usually called the effective mass (m^*).

The ratio of effective mass to free electron mass (m^*/m_o) has values slightly above or below 1.

To find an expression for the effective mass, we will calculate the group velocity,

$$v_g = \frac{d\omega}{dk}$$

where ω is the angular frequency of the de Broglie waves.

k is the wave vector and $k = 2\pi/\lambda$.

The energy of the particle is given by the relation, $E = \hbar\omega$

Hence we can write the group velocity as, $v_g = \frac{1}{\hbar}\left(\frac{dE}{dk}\right)$ ...(1)

The acceleration is given by,

$$a = \frac{dv_g}{dt} = \frac{1}{\hbar}\frac{d^2E}{dk^2}\cdot\frac{dk}{dt} \quad ...(2)$$

The crystal momentum,

$$p = \hbar k$$

Therefore, $$\frac{dp}{dt} = \hbar \frac{dk}{dt}$$

Combining equations (2) and (3), gives

$$a = \frac{1}{\hbar^2} \cdot \frac{d^2E}{dk^2} \cdot \frac{dp}{dt}$$

$$= \frac{1}{\hbar^2} , \frac{d^2E}{dk^2} . F$$

where F = Froce = Rate of change of momentum from Newton's law,

$$a = \frac{F}{M*}$$

Combining equations (4) and (5), we get,

$$\frac{F}{M*} = \frac{1}{\hbar^2} \frac{d^2E}{dk^2} . F$$

$$\Rightarrow \qquad M^* = \hbar^2 \left(\frac{d^2E}{dk^2}\right)^{-1}$$

Hence the effective Mass M^* is inversely proportional to the curvature of an electron band. It is not constant.

It is clear that :

1. If the curvature of E versus k is larger, then **M^* is small**
2. If the curvature of E versus k is small then **M^* is large.**

Effective mass can either be positive or negative. **An electron with a n** effective msss is called "defect electron" or an **"electron hole". Am electr** pair is called an "excition".