UNIT – 1

ELECTRICAL PROPERTIES OF MATERIALS

CONTENTS

1.8. Fermi - Dirac Distribution Function

In a metal at zero Kelvin temperature, the highest filled energy level is called the **Fermi level** and the energy possessed by the electrons in that level is known as **Fermi energy**.

Fermi-Dirac statistics deals with the particles having half integral spin like electron. Fermi distribution function gives information about the distribution of electrons among the various energy levels as a function of temperature. It is given by,

$$F(E) = \frac{1}{1 + e^{(E-E_F)/K_BT}}$$

Where,

F(E) - is the Fermi distribution function.

E_F – is the Fermi energy.

K_B - is the Boltzmann constant.

T - is the temperature.

E - is the total energy.

The probability value F(E) lies between 0 and 1.

- If F(E) = 1, the energy level is occupied by an electron.
- If F(E) = 0, the energy level is vacant.
- If F(E) = 0.5, then there is a 50% chance for finding the electron in the energy level.

Significance of Fermi energy

- It gives information about the velocities of the electrons which participate in ordinary electrical conduction.
- Fermi velocity of conduction electron is can be calculated from it.
- It is used to understand the specific heat capacity of solids at ordinary temperature.

1.8.1. Effect of Temperature on Fermi Function

The Fermi level varies with respect to temperature as given below

At 'T' is equal to zero Kelvin temperature (T = 0 K)

At T=0 K, the electrons are filled up to a maximum energy level called Fermi energy level E_F. All the energy levels above the Fermi energy levels are empty.

Case (i)

At T = 0 k and E < E_F

$$F(E) = \frac{1}{1+e^{-\infty}} = \frac{1}{1} = 1$$

Therefore 100% chance for the electron to be filled with in the Fermi energy level.

Case (ii)

At T = 0 K and E >E_F

$$F(E) = \frac{1}{1+e^{\infty}} = \frac{1}{\infty} = 0$$

Therefore 0% chance for the electron not to be filled within the Fermi energy level.

Case (iii)

At T = 0 K and E= E_F

$$F(E) = \frac{1}{1+e^{0}} = \frac{1}{1+1} = \frac{1}{2} = 0.5$$

Therefore 50% chance for the electron to be filled and not to be filled with in the Fermi energy level. The Fermi function at '0' Kelvin can also be graphically represented in given figure. The graph clearly shows that the curve has step like character at '0' Kelvin. Electrons with Fermi energy move with Fermi velocity and the same is related to the Fermi temperature by the relation.

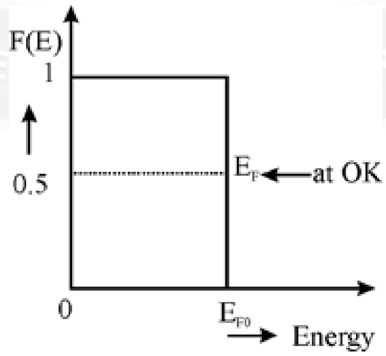

Fig 1.8.1Fermi level variation with temperature at T=0K

At any temperature other than zero

When temperature is raised slowly from absolute zero, the Fermi distribution function smoothly decreases to zero. The electrons lose their quantum mechanical character and it reduces to classical Boltzmann distribution.

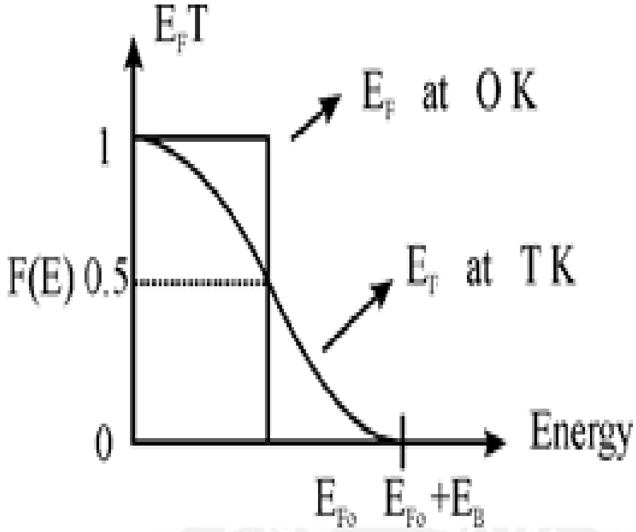

Fig 1.8.2 Fermi level variation with temperature at T