Fermi dirac distribution and Boltzmann Approximation

Introduction :- Electrons and holes play very essential role in transfer of electricity in Semiconductors.

* These particles are arrange at different energy level in Semiconductor.

* The movement of electrons from one energy level to other generates electricity.

* There are many theses proposed and explaining the behavior of electrons. But some behavior of electrons such as the independence of emission of current on temperature etc. still remained mystery.

* Then a breakthrough statistics. Fermi dirac distribution published/gave by Enrico fermi and Paul Dirac in 1926 helped to solve these puzzle.

* Fermi dirac distribution basically Explain the energy distribution in different energy state in Semiconductor.

Fermi dirac distribution function

* The probability that the available energy State "E" will be occupied by an electron at absolute temperature T under the condition of thermal Equilibrium is given by fermi dirac function.

$$\boxed{f(E) = \frac{1}{1+e^{\frac{(E-E_F)}{k_B T}}}} \quad \text{———} (1)$$

where k_B is Boltzmann

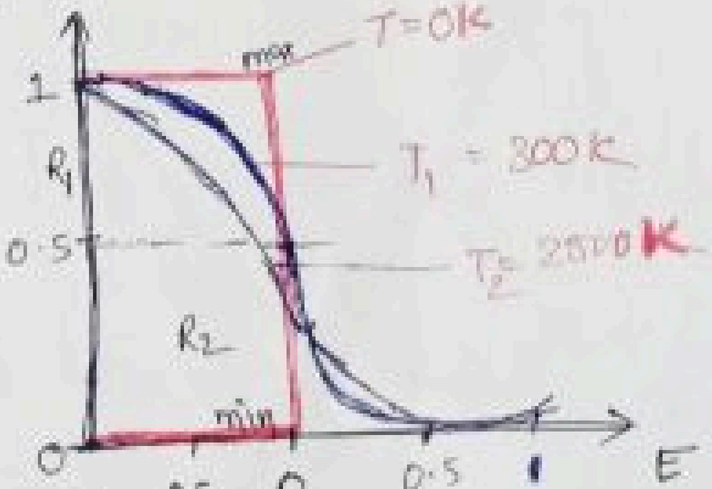
constant in 0K. { $k_B = 1.38 \times 10^{-23}$ J/K)

* ~~Df~~ (Defination)

* At temperature $T > 0K$, the distribution of electrons over a range of allowed energy level at thermal equilibrium is given by fermi dirac distribution function.

* fermi dirac distribution only gives the probability of occupancy of the state at a given energy level but doesn't provide any information about the number of states available at energy level.

* Fermi Energy distribution and energy band diagram.



The graph drawn between probability function and fermi energy at various temp. ranges, $T = 0K$, $T = 300K$, $T = 2500K$.

At $T = 0K$ the total number of energy levels occupied by electron can be known using the fermi-Dirac function.

* There are two condition arises —

$$\left.\begin{array}{l} \text{case I} = E > E_F \\ \text{case II} = E < E_F \end{array}\right] \text{At } 0K$$

A) Case I :- when total energy is greater than fermi energy ~~than~~ $(E > E_F)$ ~~when~~ at $T = 0K$

Using Eqn (1)

$$f(E) = \frac{1}{1 + e^{\frac{(E - E_F)}{KT}}}$$

$$= \frac{1}{1 + e^{\left(\frac{+ve\ number}{0}\right)}}$$

$$= \frac{1}{1 + e^{+\infty}}$$

$$= \frac{1}{1 + \infty} = \frac{1}{\infty}$$

$$\boxed{f(E) = 0} \longrightarrow (2)$$

* This is indicates all energy level above E_F are completely ~~empty~~ empty at absolute zero temperature.

B) case II :- If fermi-energy is greater than total ~~for~~ energy ($E < E_F$) at 0K —

using Eqⁿ ①

$$f(E) = \frac{1}{1 + e^{\left(\frac{E - E_F}{KT}\right)}} \quad \text{at } T = 0K$$

$$= \frac{1}{1 + e^{\frac{(-ve\ number)}{0}}} \quad \text{at } T = 0K$$

$$= \frac{1}{1 + e^{-\infty}}$$

$$= \frac{1}{1 + 0}$$

$$\boxed{f(E) = 1} \quad \text{—— ③}$$

This is indicates all energy levels between fermi levels are completely filled up absolute zero temperature.

Hence Eqⁿ ② & ③ are satisfy the graph of fermi dirac distribution function.

* If temperature greater than absolute temp and $E < E_F$, than the exponential will be negative. (In graph R_1)

In region R_1, $f(E)$ starts at 0.5 and tends to increase to wards 1

* If temp. greater than absolute temperature and $E > E_F$, then exponential will be positive.
~~and~~ In region R_2, $f(E)$ starts from 0.5 and tends to ~~the~~ decrease towards 0.

* Fermi Dirac Distribution Boltzmann approximation —

Maxwell Boltzmann distribution to the commonly used Fermi dirac distribution approximation. Fermi dirac distribution is given by —

$$f(E) = \frac{1}{1 + e^{\left(\frac{E - E_F}{k_B T}\right)}}$$

Maxwell Reduces above equation and proceeds new modified eqn which is —

$$\boxed{f(E) = Ae^{\left(\frac{E_F - E}{k_B T}\right)}}$$

when the difference between the carriers energy and fermi energy level is large compared to the term 1 in denominator can be neglected.

* for the application of fermi dirac distribution the electron must follow paulis exculusive principle, which is the important at high doping.

* But maxwell Boltzmann distribution neglects this principle, thus ~~[illegible]~~ that approximation is limited to lowly doped ~~[illegible]~~ cases.