FERMILEVEL IN SEMICONDUCTOR

In intrinsic semiconductor, the probability of finding an electron in the conduction band is zero and the probability of finding a hole in the valence band is zero, at absolute zero i.e. T = 0°K.

Now let E_C be the lowest energy level in the conduction band while E_V be the highest energy level in the valence band. As temperature increases, equal number of electrons and holes get generated. Hence probability of finding electron in conduction band and probability of finding hole in valence band is same.

The fermi level in such a case is given by,

$$E_F = \frac{E_C + E_V}{2} \quad \text{... For intrinsic semiconductor}$$

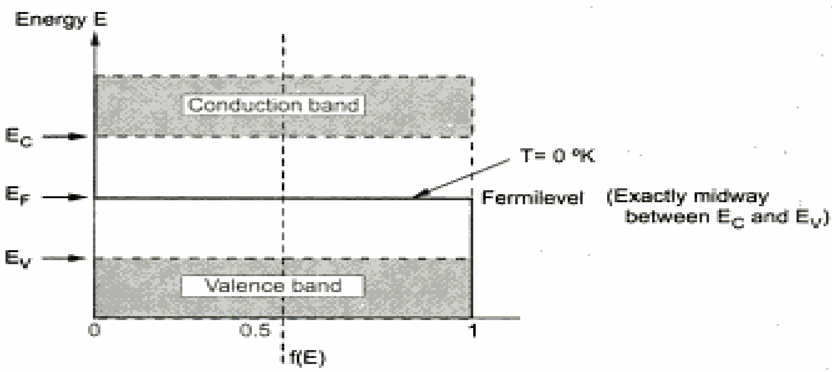

Fig. 1.15 Energy band diagram for intrinsic semiconductor

Thus in the energy band diagram, the fermi level for the intrinsic semiconductor lies in the center of the forbidden energy band. Hence the energy band diagram for intrinsic semiconductor is shown as in the Fig. 1.15. The fermi level in the center of forbidden gap indicates equal concentrations of free electrons and holes.

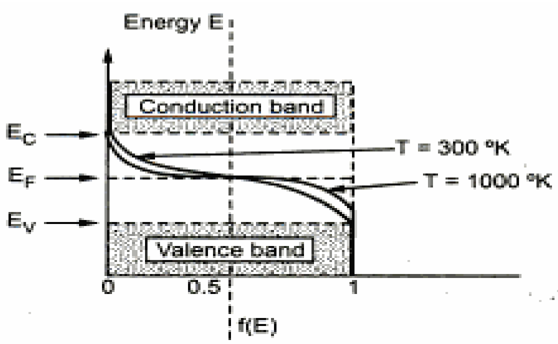

Fig. 1.16

As temperature increases, the some electrons are excited to higher energy levels and hence some states near the bottom of the conduction band E_C will be filled. While at the top of valence band E_V, the probability of occupancy is decreased, as some electrons are escaped from valence to conduction band. Hence the energy band diagram for higher temperature, is as shown in the Fig. 1.16.

The concentration of electrons in the conduction band is given by,

$$n = N_C e^{-(E_C - E_F)/kT} \quad \dots (1)$$

where $$N_C = 2\left(\frac{2\pi m_n \bar{k} T}{h^2}\right)^{\frac{3}{2}} \quad \dots (2)$$

The concentration of holes in the valence band is given by,

$$p = N_v e^{-(E_F - E_V)/kT} \quad \dots (3)$$

where $$N_v = 2\left(\frac{2\pi m_p \bar{k} T}{h^2}\right)^{\frac{3}{2}} \quad \dots (4)$$

and m_p = effective mass of a hole

In pure intrinsic semiconductor,

$$n = p = n_i$$

So equating equations (1) and (3) we get,

$$N_C e^{-(E_C - E_F)/kT} = N_v e^{-(E_F - E_V)/kT}$$

$$\frac{N_C}{N_V} = \frac{e^{-(E_F - E_V)/kT}}{e^{-(E_C - E_F)/kT}} = e^{(-E_F + E_V + E_C - E_F)/kT}$$

Taking logarithm of both sides

$$\ln \frac{N_C}{N_V} = \frac{-E_F + E_V + E_C - E_F}{kT}$$

$$\therefore \quad \ln \frac{N_C}{N_V} = \frac{E_C + E_V - 2E_F}{kT}$$

$$\therefore \quad \boxed{E_F = \frac{E_C + E_V}{2} - \frac{kT}{2} \ln \frac{N_C}{N_V}} \quad \dots (5)$$

If effective masses of electron and hole, m_n and m_p are same, $N_C = N_V$.

$$\therefore \quad \boxed{E_F = \frac{E_C + E_V}{2}} \quad \dots (6)$$

EFFECT OF TEMPRATURE ON PN JENCTION DIODE

The temperature has following effects on the diode parameters,

1. The cut-in voltage decreases as the temperature increases. The diode conducts at smaller voltages at large temperature.
2. The reverse saturation current increases as temperature increases.

This increase in reverse current I_o is such that it **doubles at every 10°C rise in temperature**. Mathematically,

$$\boxed{I_{o2} = 2^{(\Delta T/10)} I_{o1}}$$

where I_{o2} = Reverse current at T_2 °C

I_{o1} = Reverse current at T_1 °C

$\Delta T = (T_2 - T_1)$

3. The voltage equivalent of temperature V_T also increases as temperature increases.

3. The voltage equivalent of temperature V_T also increases as temperature increases.

4. The reverse breakdown voltage increases as temperature increases.

This is shown in the Fig. 2.32.