Atomic Structure and Semiconductor

Lecture - 34

(10/04/2021)

B.Sc (Electronics)
TDC PART - I
Paper – 1 (Group – B)
Chapter – 4
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➢ Introduction of Fermi Level in an Intrinsic Semiconductor

⇨ Those semiconductors in which impurities are not present are **known as intrinsic semiconductors.** The **electrical conductivity** of the semiconductor depends upon the **total number of electrons** moved to the **conduction band** from the **valence band**. Eg. **Silicon ($_{14}Si$)** and **Germanium ($_{32}Ge$).**

⇨ If the t**emperature will be maintained at zero Kelvin**, then the **valence band** will be full of **electrons.** So, at **such a low temperature range** it is impossible to cross the **energy barrier**. **It will act as an insulator at zero Kelvin.** The minimum energy required to the break the **covalent bond for germanium crystal** is **0.72 eV** and **for silicon crystal** its value is **1.1 eV.**

⇨ At **room temperature thermal energy excite** some **electrons** present in valence band, electrons to shift to the conduction band. So, the semiconductor will be able to show some electrical conductivity.

⇨ As the temperature increases, the electrons movement from the **valence band** to the **conduction band will also increase**. The **holes** will be **left behind** in the **valence band** in place of electrons. This vacancy created by the electron after the breakage of the covalent bonding is **known as hole**.

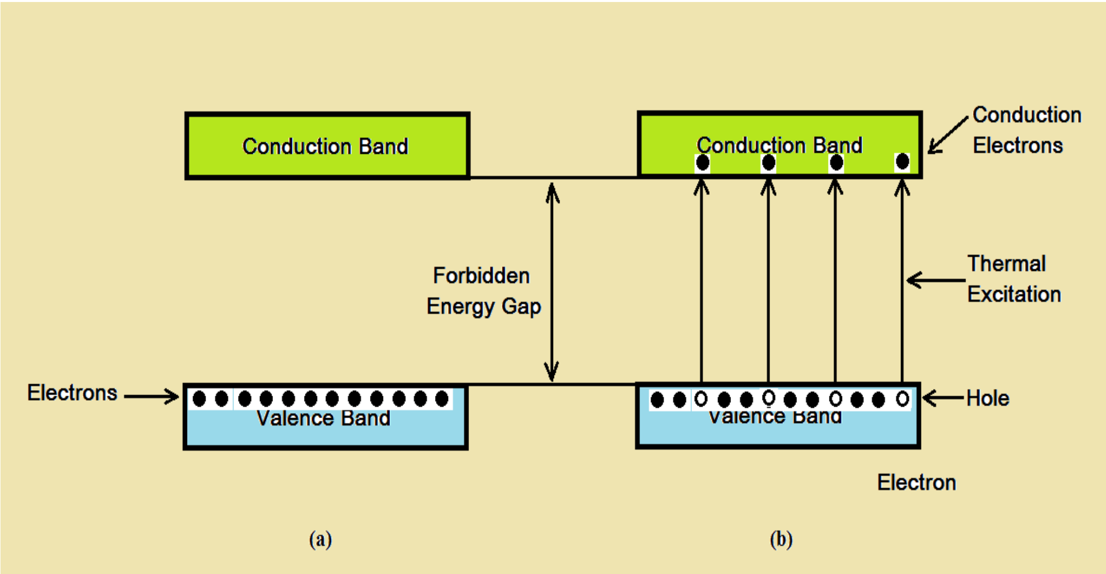

Fig. (1) Shown Energy Band diagram of Intrinsic Semiconductor at **(a) T = 0 K (b) Temperature > 0 K .**

⇨ **Hence, the probability of occupation of energy levels in valence band and conduction band is called Fermi level.** At absolute zero temperature (at 0K) intrinsic semiconductor **acts as perfect insulator**. However as the temperature increases **free electrons** and holes pairs get generated.

⇨ In intrinsic or pure semiconductor, the number of holes in valence band is equal to the number of electrons in the conduction band.

⇨ **Hence, the probability of occupation of energy levels in conduction band and valence band are equal.** Therefore, the Fermi level for the intrinsic semiconductor lies in the middle of forbidden band.

⇨ Fermi level in the middle of forbidden band indicates equal concentration of free electrons and holes.

⇨ At temperature $T\,^0K$, the electron concentration 'n' is equal to hole concentration 'p' in an intrinsic semiconductor i.e., $n = p$.

⇨ The **hole-concentration in the valence band** is given as,

⇨ $$p = n_v = N_V\, e^{\frac{-(E_F - E_V)}{K_B T}} \quad \text{...} \quad (1)$$

⇨ The **electron-concentration in the conduction band** is given as,

⇨ $$n = n_c = N_c\, e^{\frac{-(E_C - E_F)}{K_B T}} \quad \text{...} \quad (2)$$

where,

- K_B is the Boltzmann constant,
- T is the absolute temperature of the intrinsic semiconductor,
- Nc is the effective density of states in the conduction band,
- Nv is the effective density of states in the valence band,
- n_c is the number / density of electrons in conduction band,
- n_v is the number / density of holes in valence band,
- e is the electronic charge of an electron.

(1) The number of electrons in the conduction band is depends on effective density of states in the conduction band and the distance of Fermi level from the conduction band.

(2) The number of holes in the valence band is depends on effective density of states in the valence band and the distance of Fermi level from the valence band.

(3) For an intrinsic semiconductor, the electron-carrier concentration is equal to the hole-carrier concentration.

⇨ It can be written as,

⇨ $$p = n = n_i \quad \text{...} \quad \textbf{(3)}$$

where,

- p = hole-carrier concentration
- n = electron-carrier concentration and
- n_i = intrinsic carrier concentration

⇨ Thus from above discussion, **Fermi level for intrinsic semiconductor** is given as,

$$\therefore \; E_F = \frac{E_C + E_V}{2} = \frac{E_G}{2} \quad \text{...} \quad \textbf{(4)}$$

$$\text{or, } E_F = \frac{E_G}{2} \quad \text{...} \quad \textbf{(5)}$$

where ,

- E_F is the Fermi level
- E_C is the Energy of conduction band
- E_V is the Energy of valence band

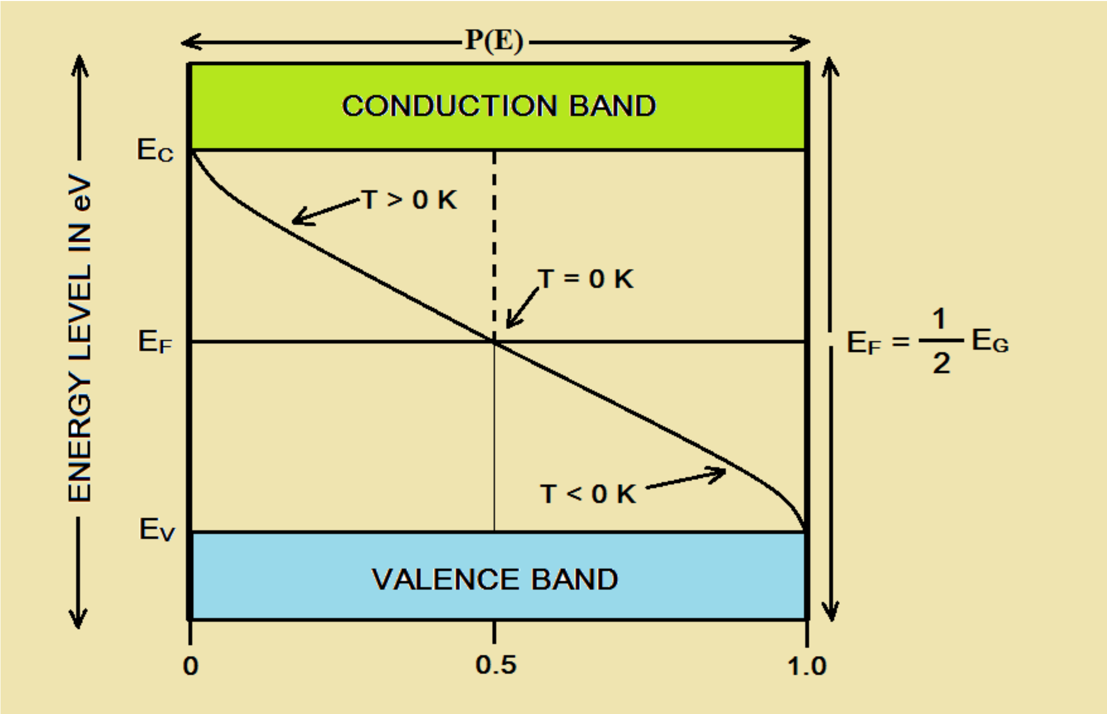

Fig. (2) Shown in an Intrinsic Semiconductor, the Fermi Level lies midway between the Conduction and Valence Bands.

⇨ Therefore, from the above discussion, we can say that, **Fermi level in an intrinsic semiconductor lies in the middle of the Forbidden Gap (E_g).**

to be continued ....

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