SNS COLLEGE OF ENGINEERING

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AN AUTONOMOUS INSTITUTION

Approved by AICTE, New Delhi and Affiliated to Anna University, Chennai.

UNIT -III SEMICONDUCTOR PHYSICS

TOPIC – III CARRIER CONCENTRATION IN AN INTRINSIC SEMICONDUCTOR

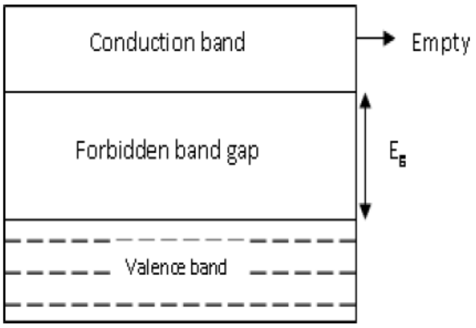
Effect of Temperature on intrinsic semiconductors

i. **At absolute zero**:

At absolute zero, all the electrons are tightly bound to the nucleus.

The inner orbit electrons are bound, whereas the valence electrons are bonded, with covalent bond, with other atoms.

Hence at absolute zero, no valence electron can reach the conduction band to become free electron.



So the valence band is completely filled and the conduction band is empty.

ii. **At absolute zero**:

At absolute zero, all the electrons are tightly bound to the nucleus.

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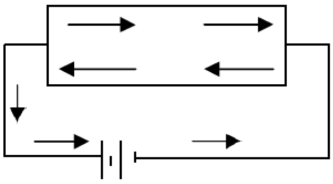


Hence at absolute zero, no valence electron can reach the conduction band to become free electron.

So the valence band is completely filled and the conduction band is empty.

iii. **Above absolute zero**:

When the temperature is raised some of the covalent bonds break due to thermal energy supplied.

Due to the breaking of bonds the electrons are released from the covalent bonds and become free electrons.

Now if a potential difference is applied across the semiconductor, these free electrons move with respect to field direction and produce a tiny electric current as shown in fig.

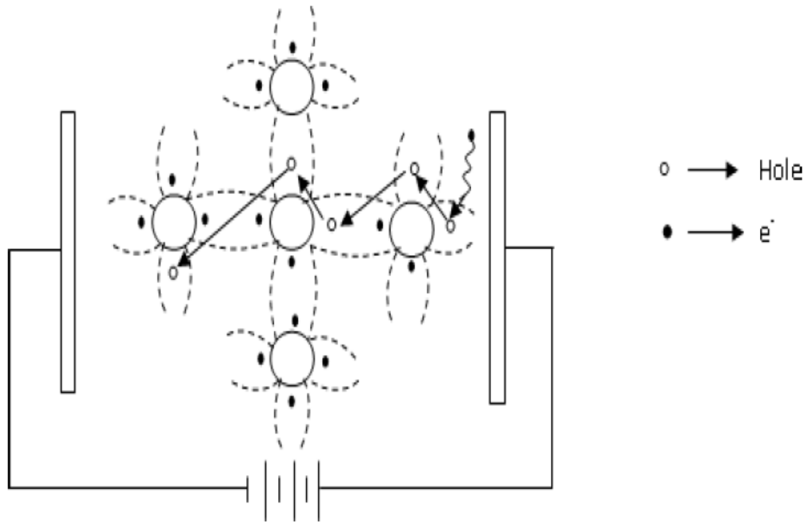
This shows that the resistance of semiconductor decreases with the rise in temperature. i.e., it has **Negative temperature co efficient of resistance**.

The no. of free electrons that move to conduction band will be exactly equal to the number of holes created in the valence band.

Hole Current

Similar to the normal current which is due to free electrons another current called the hole current also flows in the semiconductor.

Due to thermal energy if one electron enters conduction band from valence band, one hole is created in the valence band. Due to thermal energy hole- electron pairs are created.



Definition: It is noted that hole current is due to the movement of valence electrons from one covalent bond to another bond.

CARRIER CONCENTRATION IN INTRINSIC SEMICONDUCTORS

We know at 0 K intrinsic pure semiconductor behaves as insulator.

But as temperature increases some electrons move from valence band to conduction band as shown in figure.

Therefore both electrons in conduction band and holes in valence band will contribute to electrical conductivity.

Assume that electron in the conduction band is a free electron of mass m_e^* and the hole in the valence band behaves as a free particle of mass m_h^*.

The electrons in the conduction band have energies lying from E_c to ∞ and holes in the valence band have energies from $-\infty$ to E_v as shown in figure.

$$n_i^2 = N_e N_h$$

$$n_i^2 = 2\left[\frac{2\pi m_e^* K_B T}{h^2}\right]^{3/2} \exp\left[\frac{E_F - E_c}{K_B T}\right] 2\left[\frac{2\pi m_h^* K_B T}{h^2}\right]^{3/2} \exp\left[\frac{E_V - E_F}{K_B T}\right]$$

$$n_i^2 = 4\left[\left[\frac{2\pi K_B T}{h^2}\right]^{3/2}\right]^2 \left[m_e^* m_h^*\right]^{3/2} \exp\left[\frac{-\left[E_c - E_V\right]}{K_B T}\right]$$

$$n_i^2 = 4\left[\left[\frac{2\pi K_B T}{h^2}\right]^{3/2}\right]^2 \left[m_e^* m_h^*\right]^{3/2} \exp\left[\frac{-E_g}{K_B T}\right]$$

$$n_i = \left[4\left[\left[\frac{2\pi K_B T}{h^2}\right]^{3/2}\right]^2 \left[m_e^* m_h^*\right]^{3/2} \exp\left[\frac{-E_g}{K_B T}\right]\right]^{1/2}$$

$$n_i = 2\left(\frac{2\pi K_B T}{h^2}\right)^{3/2} \left[m_e^* m_h^*\right]^{3/4} \exp\left(\frac{-E_g}{K_B T}\right)^{1/2}$$

$$\boxed{n_i = 2\left[\frac{2\pi K_B T}{h^2}\right]^{3/2} \left[m_e^* m_h^*\right]^{3/4} \exp\left[\frac{-E_g}{2K_B T}\right]} \quad \dots (12)$$