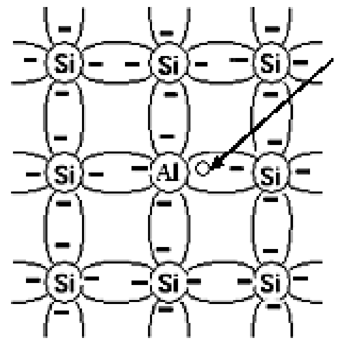
P-TYPE SEMICONDUCTOR

When trivalent impurity such as aluminum, boron, gallium or indium is added to pure silicon, it forms 3 covalent bonds with the neighboring 3 silicon atoms while the fourth bond is not completed due to the deficiency of one electron. Thus the trivalent impurity atom has a tendency to accept one electron from neighboring silicon atom to complete the fourth covalent bond. The energy level corresponding to the electron deficiency that is 'hole' is located above the valence bond and is called acceptor level.



In this type of semiconductor majority charge carriers are holes and minority charge carriers are electrons, called p-type semiconductor.

CONDUCTIVITY OF EXTRINSIC SEMICONDUCTORS

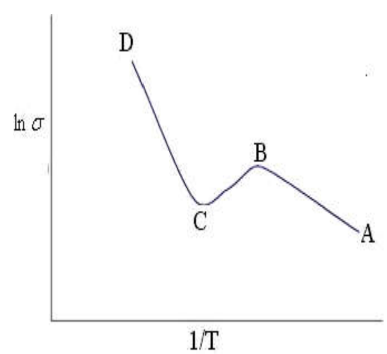
The expression for conductivity for n-type semiconductors is
$\sigma_e = ne\mu_e$ ---------- (1) and

For p-type material is $\sigma_p = ne\mu_h$ --------- (2)

Where μ_e and μ_h are mobilities of electrons and holes.

Under the condition of thermal equilibrium electron and holes are uniformly distributed in semiconductor and the average velocity of charge carriers is zero, no current flows.

Conductivity is temperature dependent as shown in figure.



At low temp the conductivity increases with increase of temperature. This is due to increase in the no. of conduction electrons due to ionization of donor impurities. Conductivity reaches maximum value B in the graph all donors is ionized. Conductivity decreases further increase with temperature. This is due to decrease of mobility because of scattering of electrons from the periodic potential field. A sharp rise in conductivity from C to D is due to large increase in intrinsic conductivity.

DRIFT & DIFFUSION

The net current that flows across semi conducting crystal has two components.

(i) Drift current
(ii) Diffusion current

DRIFT CURRENT

When voltage is applied electrons attracted towards the positive potentials and holes attracted towards the negative potential. This net movement of charge carriers is called drift.
Due to the application of voltage charge carriers attain drift velocity V_d , which is proportional to the electric field E.

HALL EFFECT

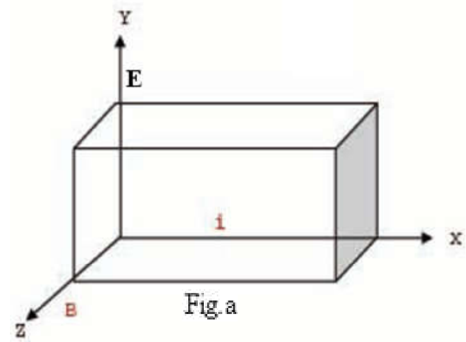


Fig.a

When a semiconductor carrying current 'i' is placed in a magnetic field which is perpendicular to the direction of current, an electric field is developed across the material in a direction perpendicular to both the current direction and magnetic field direction. This phenomenon is known as Hall Effect.

Explanation

Consider a piece of semiconductor in which current passing along x-axis. When a magnetic field B is applied along z-direction an electric field is appeared along y-direction.
If the sample is p-type semiconductor holes move with velocity v in x-direction. As they move across the semiconductor these holes experience a transverse force due to magnetic field. This force drives the holes on the lower surface as shown in figure. As a result the lower surface becomes positively charged and upper surface becomes negatively charged and creating Hall field along y-direction.

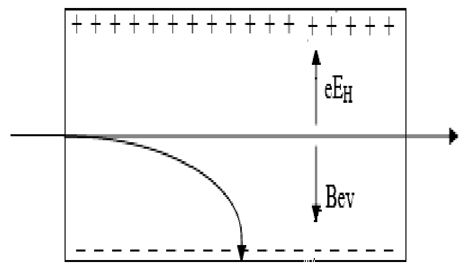


Fig.b N-Type Semiconductor

If the sample is an n-type semiconductor majority charge carriers are electrons, these electrons experience a force 'Bev' in downward direction and lower face gets negatively charged and upper face gets positively charged which is shown in fig.b

Consider a rectangular slab of n-type semiconductor carrying current in positive x-direction under the magnetic field electrons are deflected to the lower surface because of force 'Bev' due to magnetic field and upper surface gets positively charged because of this electric field a force 'eE_H' acts on electrons in upward direction. The two opposing forces 'Bev' and 'eE_H' establish equilibrium. So

$$Bev = eE_H$$

$$Bv = E_H \text{ ---------- } (1)$$

Let 'J' be the current density then

$$J = nev \quad \text{or} \quad v = \frac{J}{ne} \text{ --------- } (2)$$

From (1) and (2), $\frac{BJ}{ne} = E_H$ -------- (3)

Hall Effect depends on the current density J and magnetic field B.

$$E_H \propto JB$$

$E_H = R_H JB$ ----------- (4) Where R_H is Hall coefficient.

From (3) and (4), $R_H = -\frac{1}{ne}$ ----------- (5)

-ve sign is used because the electric field developed in –ve y-direction.

For p-type semiconductors,

$$R_H = \frac{1}{pe} \text{ ---------- (6) where p is hole density.}$$

DETERMINATION OF HALL COEFFICIENT (R_H)

If V_H be the Hall voltage across the sample of thickness‘t’

$$E_H = \frac{V_H}{t} \text{ --------- (7)}$$

From (4) and (7),

$$R_H JB = \frac{V_H}{t} \quad \text{or} \quad V_H = R_H JB \times t \text{ ------------ (8)}$$

If ‘b’ be the width of the sample then current density $J = \frac{I}{A}$

$$V_H = \frac{R_H IxBxt}{bxt} \quad \text{or}$$

$$R_H = \frac{V_H bxt}{IxB} \text{ ---------- (9)}$$

SIGNIFICANCE OF HALL EFFECT

1. By means of Hall Effect we can assess the type of semiconductor whether it is n-type or p-type. Hall coefficient is negative for n-type material.

2. Charge carrier concentration can be evaluated by means of Hall Effect.

$$R_H = \frac{1}{ne} \text{ or } n = \frac{1}{eR_H}$$

3. Mobility of charge carriers can be calculated by means of Hall Effect.

$$\sigma = ne\mu \text{ and } R_H = \frac{1}{ne}$$

$$\therefore \mu = R_H \sigma$$

4. Hall Effect can be used to determine the power flow in electromagnetic wave

DIRECT AND INDIRECT BANDGAP SEMICONDUCTORS

According to the band theory of solids, the energy spectrum of electrons consists of large number of allowed energy bands and separated by forbidden regions. The lowest point of the C.B is called conduction band edge and the highest point in V.B is called valence band valence band edge. The gap between them is called band bap or forbidden gap. Based on the band gap semiconductors are classified into two types.

(i) Direct band gap semiconductors and
(ii) Indirect band gap semiconductors

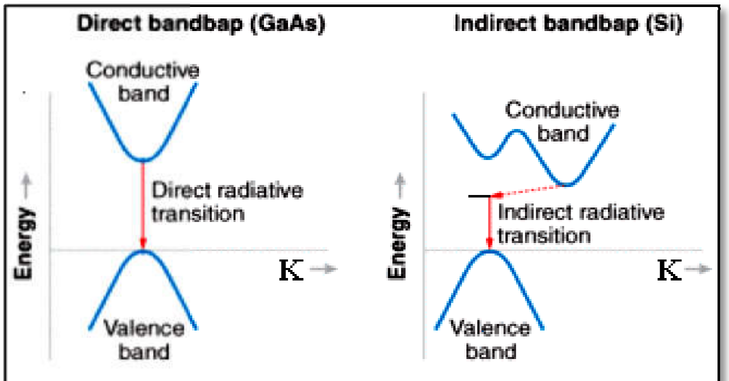


Fig.a Fig.b

DIRECT BAND GAP SEMICONDUCTORS

- Fig.a shows E-K curve for direct band gap semiconductor. In this case the maximum of the valence band and the minimum of the conduction band occurs at the same value of the 'K'.
- In direct band gap semiconductors electrons in the C.B directly recombine with the holes in the V.B.
- Energy is released in the form of photons. So LED's and Lasers diodes are prepared with them.
- In direct band gap semiconductors life time of charge carries is very less. (i.e excited electrons cannot stay long time in the higher energy states)
- Direct band gap semiconductors are formed by compound semiconductors. Ex. InP, GaAs etc.

INDIRECT BAND GAP SEMICONDUCTORS

- Fig b shows E-K curve for direct band gap semiconductor. In this case the maximum of the valence band and the minimum of the conduction band cannot occur at the same value of the 'K'.
- In indirect band gap semiconductors electrons in the C.B do not directly recombine with the holes in the V.B. Electrons are trapped in the energy gap called trapping centers.
- Energy is released in the form of heat.
- In indirect bandgap semiconductors life time of charge carries is longer. So they are used to amplify the signals in diodes and transistors.
- Indirect band gap semiconductors are formed by elemental semiconductors. Ex.Si, Ge.