Unit III

SEMICONDUCTING MATERIALS

3.5. HALL EFFECT:

STATEMENT

When a magnetic field (B) is applied perpendicular to a current carrying conductor or semiconductor a potential difference (electric field) is developed inside the conductor in a direction perpendicular to both current and magnetic field. This phenomenon is known as Hall Effect and the voltage thus generated is called Hall voltage

THEORY

3.5.1.Hall effect in n- type semiconductor

Let us consider a n-type semiconductor material in the form of rectangular slab. In such a material current flows in X –direction and magnetic field B applied in Z- direction. As a result, Hall voltage is developed along Y –direction as shown in figure

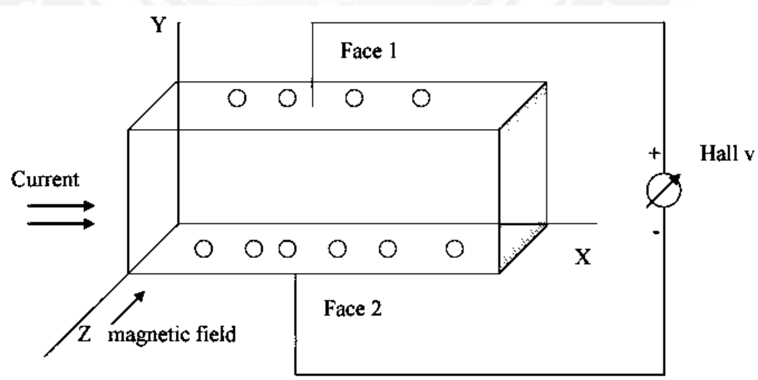

Fig **3.5**.1-Hall Effect in N type semiconductor

Since the direction of current is from left to right the electrons moves fromright to left . When a magnetic field is applied the electrons are moving towards the bottom of the semi conductor.

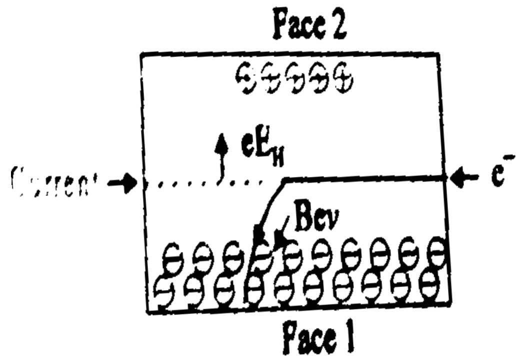

Fig **3.5**.2-Hall Effect

Lorentz force= $-e E_H$ ---(1)

Magnetic deflecting force = $-$ Bev ---(2)

At equilibrium

$$-e E_H = -Bev$$

$$E_H = Bv \quad ---(3)$$

We know the current density J_x in the X- direction is

$$J_x = -ne v$$

$$v = - J_x / ne \quad ---(4)$$

Substituting equation (4) in equation (3)

we get $$E_H = - B J_x / ne \quad --------------(5)$$

$$E_H = R_H . J_x . B \quad ---------------(6)$$

Where R_H is known as the Hall co –efficient, is given by$R_H = - (1 / ne)$ (7)

The negative sign indicates that the field is developed in the negative Y –direction.

3.5.2 Hall effect in p –type semiconductor

Let us consider a p –type semiconducting material for which the current is passed along X – direction from left to right and magnetic field is applied along Z – direction as shown in fig. since the direction of current is from left to right, the holes will also move in the same direction as shown in fig.

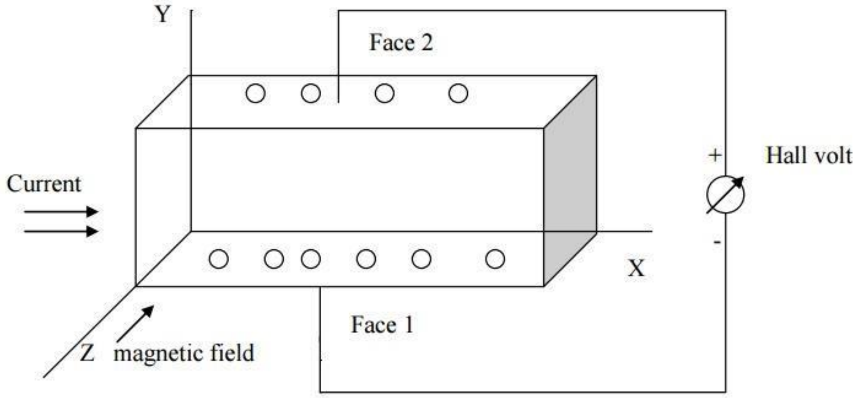

Fig **3.5**.3-Hall Effect in P type semiconductor

Now due to magnetic field applied the holes moves towards downward direction with velocity v and accumulates at the face (1). A potential difference is established between face (1) and (2) in the positive Y - direction.

Here, the force due to potential difference = $-e E_H$ (8)

Force due magnetic field = Bev-----(9)

At equilibrium equation (1) = equation (2)$e E_H = Bev$

$$E_H = Bv \text{ -------------- } (10)$$

We know the current density Jx in the X- direction is

$$J_x = n_h ev$$

$$v = J_x / n_h e \text{ ------------- } (11)$$

Substituting equation (4) in equation (3) we get

$$E_H = B J_x / n_h e$$

$$E_H = R_H . J_x . B$$

Where RH is known as the Hall co –efficient, is given by$R_H = (1 / n_h e)$ The positive sign indicates that the field is developed in the positive Y –direction

3.5.3.Hall coefficient in terms of hall voltage

If the thickness of the sample is t and the voltage developed is VH, thenHall voltage

$$V_H = E_H .t$$

Substituting equation (6)in equation (13), we have

$$V_H = R_H J_x B .t$$

b is the width of the sample then

$$\text{Current density} = J_x = I_x / bt$$

There fore

$$V_H = R_H B .t I_x / bt$$

$$V_H = R_H B I_x / b$$

$$R_H = V_H b / I_x B$$

This is the expression for Hall coefficient.

3.5.4.EXPERIMENTAL DETERMINATION OF HALL EFFECT

A semiconducting material is taken in the form of a rectangular slab of thickness t and breadth b. A suitable current I_x ampere is passed through this sample alongX- axis by connecting it to a battery

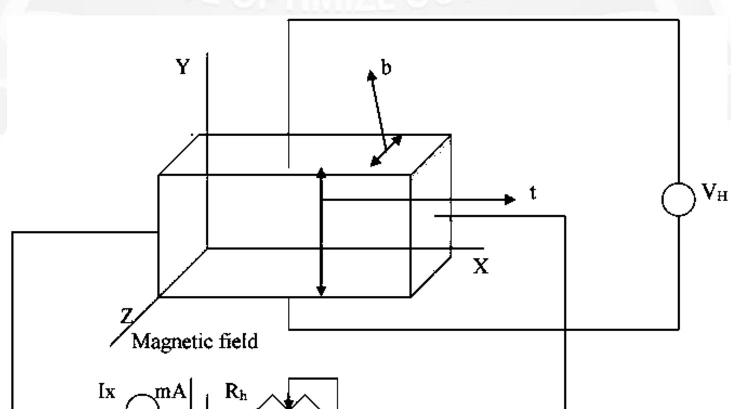

Fig 2,6.4-Experiment for Hall Effect

Now a semiconductor is placed in a magnetic field . A voltage is developed in the specimen which can be measured by using the voltmeter connecting with the specimen.

Then by using the formula

$$\text{Hall coefficient, } R_H = \frac{V_H\, b}{I x\, B}$$

Hall coefficient can be calculated.

2.6.5.APPLICATIONS OF HALL EFFECT

- It is used to determine whether the material is p-type or n-type semiconductor. (ie) if RH is negative then the material n-type. If the RH is positive then the materialp-type.
- It is used to find the carrier concentration
- It is used to find the mobility of charge carriers μe, μh. It is used to find the sign of the current carrying charges.
- From the hall coefficient, carrier concentration and mobility can bedetermined.