

**SEMICONDUCTING MATERIALS****CONTENTS****2.6 HALL EFFECT:****2.6.1.Hall effect in n- type semiconductor****2.6.2 Hall effect in p –type semiconductor****2.6.3.Hall coefficient in terms of hall voltage****2.6.4.Experimental Determination Of Hall Effect****2.6.5.Applications Of Hall Effect****2.6 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****2.6.1.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

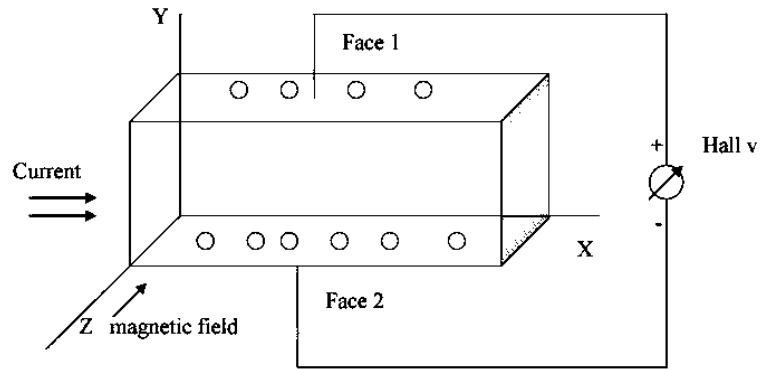


Fig 2,6.1-Hall Effect in N type semiconductor

Since the direction of current is from left to right the electrons move from right to left. When a magnetic field is applied the electrons are moving towards the bottom of the semiconductor.

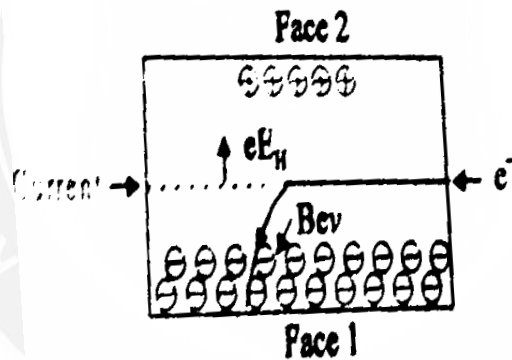


Fig 2,6.2-Hall Effect

$$\text{Lorentz force} = -e E_H \quad \text{---(1)}$$

$$\text{Magnetic deflecting force} = -Bev \quad \text{---(2)}$$

At equilibrium

$$-e E_H = -Bev$$

$$E_H = Bv \quad \text{---(3)}$$

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

$$J_x = -ne v$$

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

Substituting equation (4) in equation (3)

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

$$E_H = R_H \cdot J_x \cdot B \quad \text{-----(6)}$$

Where  $R_H$  is known as the Hall coefficient, is given by  $R_H = - (1 / ne) \quad (7)$

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

### 2.6.2 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.

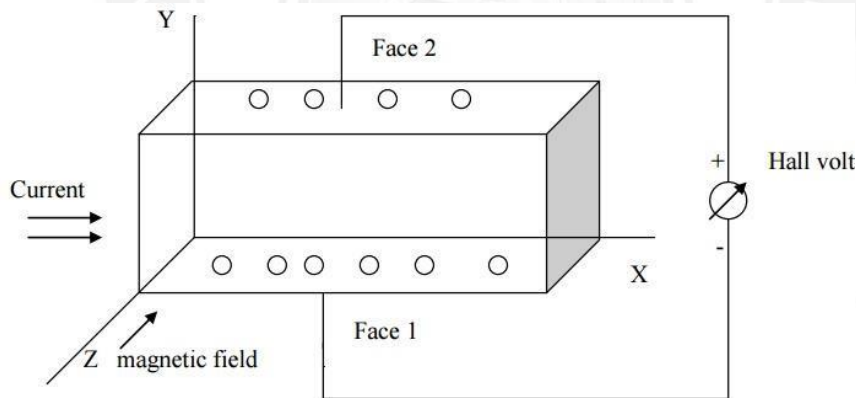


Fig 2,6.3-Hall Effect in P type semiconductor

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 =  $-e E_H \quad (8)$

$$\text{Force due magnetic field} = Bev \quad \text{----- (9)}$$

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

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

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

$$J_x = n h e v$$

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

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

$$E_H = B J_x / n_h e$$

$$E_H = R_H \cdot J_x \cdot B$$

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

### 2.6.3.Hall coefficient in terms of hall voltage

If the thickness of the sample is  $t$  and the voltage developed is  $V_H$ , then Hall voltage

$$V_H = E_H \cdot t$$

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

$$V_H = R_H J_x B \cdot t$$

$b$  is the width of the sample then

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

There fore

$$V_H = R_H B \cdot t I_x / bt$$

$$V_H = R_H B I_x / b$$

$$\boxed{R_H = V_H b / I_x B}$$

This is the expression for Hall coefficient.

### 2.6.4.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 along X- axis by connecting it to a battery

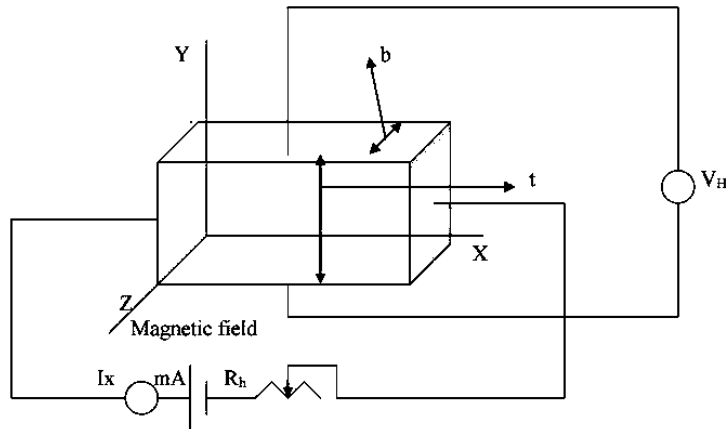


Fig 2,6.4-Experiment for Hall Effect

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  $R_H$  is negative then the material n-type. If the  $R_H$  is positive then the material p-type.
- It is used to find the carrier concentration
- It is used to find the mobility of charge carriers  $\mu_e, \mu_h$ . It is used to find the sign of the current carrying charges.
- From the hall coefficient, carrier concentration and mobility can be determined.