Unit II

SEMICONDUCTING MATERIALS

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2.6 HALL EFFECT:

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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

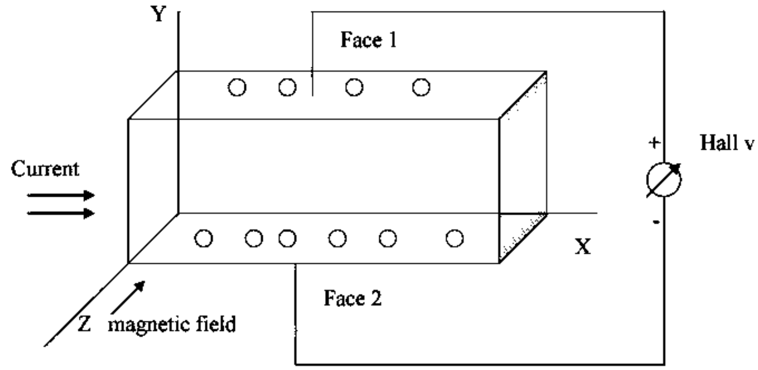

Fig 2,6.1-Hall Effect in N type semiconductor

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

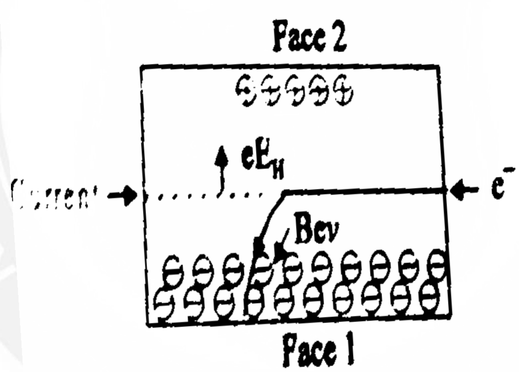

Fig 2,6.2-Hall Effect

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

Magnetic deflecting force = - Bev ---(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 co –efficient, is given by$R_H = - (1 / ne)$ (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.

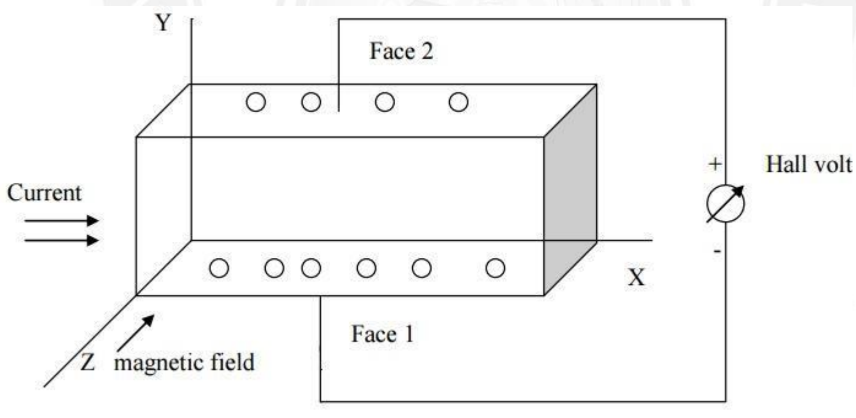

Fig 2,6.3-Hall Effect in P type semiconductor

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 = $-e E_H$ (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 R_H 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

2.6.3.Hall coefficient in terms of hall voltage

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

$$V_H = E_H\, .t$$

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

$$V_H = R_H\, Jx\, B\, .t$$

b is the width of the sample then

$$\text{Current density} = Jx = Ix / bt$$

There fore

$$V_H = R_H\, B\, .t\, Ix / bt$$

$$V_H = R_H\, B\, Ix / b$$

$$R_H = V_H\, b / I_x B$$

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 alongX- axis by connecting it to a battery

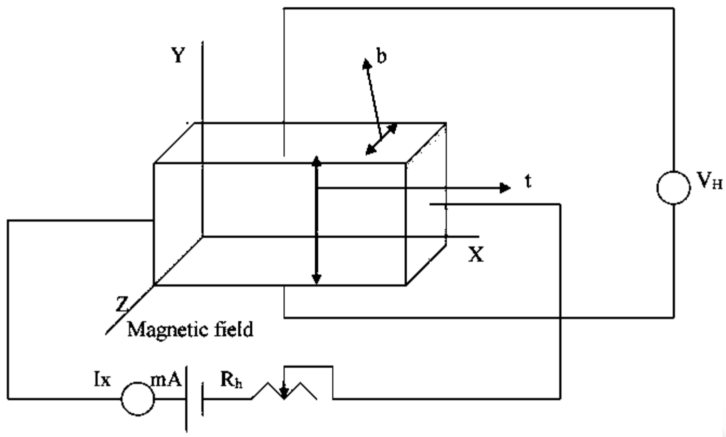

Fig 2,6.4-Experiment for Hall Effect

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

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

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.