UNIT- V

8. SEMICONDUCTOR PHYSICS

INTRODUCTION:

Semiconductors are materials whose electronic properties are intermediate between those of conductors and insulators. These electrical properties of a solid depend on its band structure. A semiconductor has two bands of importance (neglecting bound electrons as they play no part in the conduction process) the valence and the conduction bands. They are separated by a forbidden energy gap. At OK the valence band is full and the conduction band is empty, the semiconductor behaves as an insulator. Semiconductor has both positive (hole) and negative (electron) carriers of electricity whose densities can be controlled by doping the pure semiconductor with chemical impurities during crystal growth.

At higher temperatures, electrons are transferred across the gap into the conduction band leaving vacant levels in the valence band. It is this property that makes the semiconductor a material with special properties of electrical conduction.

Generally there are two types of semiconductors. Those in which electrons and holes are produced by thermal activation in pure Ge and Si are called intrinsic semiconductors. In other type the current carriers, holes or free electrons are produced by the addition of small quantities of elements of group III or V of the periodic table, and are known as extrinsic semiconductors. The elements added are called the impurities or dopants.

Intrinsic semiconductors:

A pure semiconductor which is not doped is termed as intrinsic semiconductor. In Si crystal, the four valence electrons of each Si atom are shared by the four surrounding Si atoms. An electron which may break away from the bond leaves deficiency of one electron in the bond. The vacancy created in a bond due to the departure of an electron is called a hole. The vacancy may get filled by an electron from the neighboring bond, but the hole then shifts to the neighboring bond which in turn may get filled by electron from another bond to whose place the hole shifts, and so on thus in effect the hole also undergoes displacement inside a crystal. Since the hole is associated with deficiency of one electron, it is equivalent for a positive charge of unit magnitude. Hence in a semiconductor, both the electron and the hole act as charge carriers.

In an intrinsic semiconductor, for every electron freed from the bond, there will be one hole created. It means that, the no of conduction electrons is equal to the no of holes at any given temperature. Therefore there is no predominance of one over the other to be particularly designated as charge carriers.

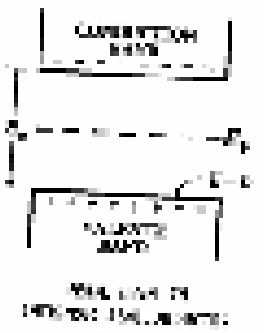
Carriers Concentration in intrinsic semiconductors:

A broken covalent bond creates an electron that is raised in energy, so as to occupy the conduction bond, leaving a hole in the valence bond. Both electrons and holes contribute to overall conduction process.

In an intrinsic semiconductor, electrons and holes are equal in numbers. Thus

$$n = p = n_i$$

Where n is the number of electrons in the conduction band in a unit volume of the material (concentration), p is the number of holes in the valance band in a unit volume of the material. And n_i, the number density of charge carriers in an intrinsic semi conductor. It is called intrinsic density.



For convenience, the top of the valence bond is taken as a zero energy reference level arbitrarily.

The number of electrons in the conduction bond is

$$n = N\,P(Eg)$$

Where P(Eg) is the probability of an electron having energy Eg. It is given by Fermi Dirac function eqn., and N is the total number of electrons in both bands.

Thus,

$$n = \frac{N}{1 + \exp[(Eg - E_F)/KT]}$$

Where E_F is the Fermi Level

The probability of an electron being in the valence bond is given by putting Eg = 0 in eqn. Hence, the number of electrons in the valence bond is given by

$$n_v = \frac{N}{1 + \exp(-E_F/KT)}$$

The total number of electrons in the semiconductor. N is the sum of those in the conduction band n and those in the valence bond n_v. Thus,

$$N = \frac{N}{1 + \exp[(Eg - EF)/KT]} + \frac{N}{1 + \exp(-E_F/KT)}$$

For semiconductors at ordinary temperature, Eg >> KT as such in equation one may be neglected when compared with $\exp\left(\frac{Eg - E_F}{RT}\right)$ Then

$$1 = \frac{1}{\exp\left(\frac{Eg - E_F}{RT}\right)} + \frac{1}{1 + \exp\left(\frac{-E_F}{RT}\right)}$$

Rearranging the terms, we get

$$\exp\frac{-Eg + E_F}{RT} = \frac{\exp(-E_F/RT)}{1 + \exp(-E_F/RT)}$$

$$\approx \exp\left(\frac{-E_F}{RT}\right)$$

or $$\exp\left(\frac{2E_F - Eg}{RT}\right) = 1$$

This leads to

$$E_F = Eg/2$$

Thus in an intrinsic semiconductor, the Fermi level lies mid way between the conduction and the valence bonds. The number of conduction electrons at any temperature T is given by

$$n = \frac{N}{1 + \exp(Eg/2KT)} \quad (\therefore E_F = Eg/2)$$

In eqn may be approximated as

$$n \approx N \exp(-Eg / 2RT)$$

From the above discussion, the following conclusions may be drawn.

a) The number of conduction electrons and hence the number of holes in an intrinsic semiconductor, decreases exponentially with increasing gap energy Eg this accounts for lack of charge carries in insulator of large forbidden energy gap.
b) The number of available charge carries increases exponentially with increasing temperature.

The above treatment is only approximate as we have assumed that all states in a bond have the same energy. Really it is not so. A more rigorous analysis must include additions terms in eqn.

The no of conduction bond, in fact is given by

$$n = \int S(E)\, P(E)\, dE$$

Where S(E) is the density of available states in the energy range between E and E + dE, and P(E) is the probability, that an electron can occupy a state of energy E.

$$S(E)\ \frac{8\sqrt{2}\,\pi\, m^{3/2}}{n^3}\, E^{1/2}$$

Inclusion of S(E) and integration over the conduction bond leads to

$$n = N_e \exp\left[(-Eg-E_F)/RT\right]$$

In a similar way, we arrive at

$$p = N_V \exp\left[-E_F/RT\right]$$

If we multiply eq: we get

$$np = n_i^2 = N_e\, N_V \exp(-Eg/RT)$$

For the intrinsic material

$$Ni = 2\,\frac{(2\pi RT)^{3/2}}{h^2}\,(m_e^*\, m_n^*)^{3/4} \exp(-Eg/2RT)$$

Notice that this expression agress with the less rigorous one derived earlier since the temperature dependence is largely controlled by the rapidly varying exponential term.

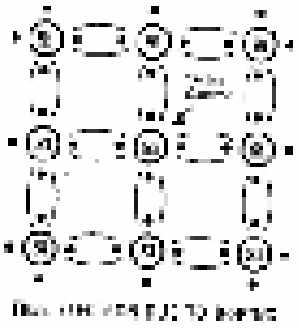
EXTRINSIC SEMICONDUCTORS:

Intrinsic Semiconductors are rarely used in semiconductor devices as their conductivity is not sufficiently high. The electrical conductivity is extremely sensitive to certain types of impurity. It is the ability to modify electrical characteristics of the material by adding chosen impurities that make extrinsic semiconductors important and interesting.

Addition of appropriate quantities of chosen impurities is called doping, usually, only minute quantities of dopants (1 part in 10^3 to 10^{10}) are required. Extrinsic or doped semiconductors are classified into main two main types according to the type of charge carries that predominate. They are the n-type and the p-type.

N-TYPE SEMICONDUCTORS:

Doping with a pentavalent impurity like phosphorous, arsenic or antimony the semiconductor becomes rich in conduction electrons. It is called n-type the bond structure of an n-type semiconductor is shown in Fig below.

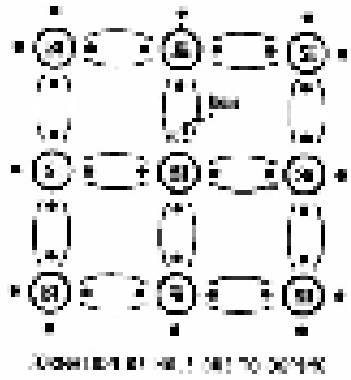


Even at room temperature, nearby all impurity atoms lose an electron into the conduction bond by thermal ionization. The additional electrons contribute to the conductivity in the same way as those excited thermally from the valence bond. The essential difference beam

the two mechanisms is that ionized impurities remain fixed and no holes are produced. Since penta valent impurities denote extra carries elections, they are called donors.

P-TYPE SEMICONDUCTORS:-

p-type semiconductors have holes as majority charge carries. They are produced by doping an intrinsic semiconductor with trivalent impurities.(e.g. boron, aluminium, gallium, or indium). These dopants have three valence electrons in their outer shell. Each impurity is short of one electron bar covalent bonding. The vacancy thus created is bound to the atom at OK. It is not a hole. But at some higher temperature an electron from a neighbouring atom can fill the vacancy leaving a hole in the valence bond for conduction. It behaves as a positively charge particle of effective mass m_h*. The bond structure of a p-type semiconductor is shown in Fig below.



Dopants of the trivalent type are called acceptors, since they accept electrons to create holes above the tope of the valence bond. The acceptor energy level is small compared with thermal energy of an electron at room temperature. As such nearly all acceptor levels are occupied and each acceptor atom creates a hole in the valence bond. In extrinsic semiconductors, there are two types of charge carries. In n-type, electrons are more than holes. Hence electrons are majority carriers and holes are minority carries. Holes are majority carries in p-type semiconductors; electrons are minority carriers.

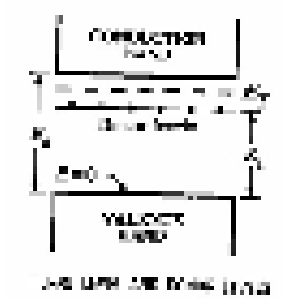
CARRIER CONCENTRATION IN EXTRINSIC SEMICONDUCTORS:

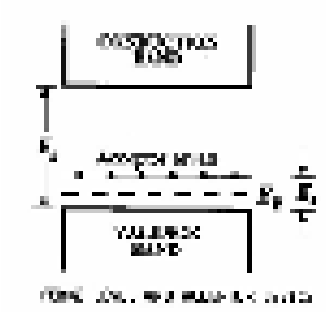
Equation gives the relation been electron and hole concentrations in a semiconductor. Existence of charge neutrality in a crystal also relates n and p. The charge neutrality may be stated as

$$N_D + p = N_A + n$$

Since donors atoms are all ionized, N_D positive charge per cubic meter are contributed by N_D donor ions. Hence the total positive charge density $= N_D + p$. Similarly if N_A is the concentration of the acceptor ions, they contribute N_A negative charge per cubic meter. The total negative charges density $= N_A + n$. Since the

semiconductor is electrically neutral the magnitude of the positive charge density must be equal to the magnitude of the total negative charge density.





n-type material : $N_A = 0$ Since $n >> p$, eqn reduces to $n \approx N_D$ i.e., in an n-type material the where subscript n indicates n-type material. The concentration p_n of holes in the n-type semiconductor is obtained from eqn i.e.,

$$n_n p_n = n^2_i$$

Thus $$p_n \approx \frac{n^2_i}{N_D}$$

Similarly, for a p-type semiconductor $p_p \approx N_A$ and $n_p \approx \frac{n^2_i}{N_A}$



Expression for electrical conductivity:

There are two types of carries in a Semiconductor electrons and holes. Both these carries contribute to conduction. The general expression for conductivity can be written down as

$$\sigma = e(n\mu_e + \rho\mu_h)$$

Where μ_e and μ_h are motilities of electrons and holes respectively.

A. Intrinsic Semiconductor; For an intrinsic Semiconductor

$$n = p = n_i$$

eqn becomes

$$\sigma_i = en_i(\mu_n + \mu_p)$$

If the scattering is predominantly due to lattice vibrations.

$$\mu_e = AT^{3/2}$$
$$\mu_h = BT^{3/2}$$

We may put $\mu_e + \mu_h = (A + B)T^{3/2} = CT^{3/2}$

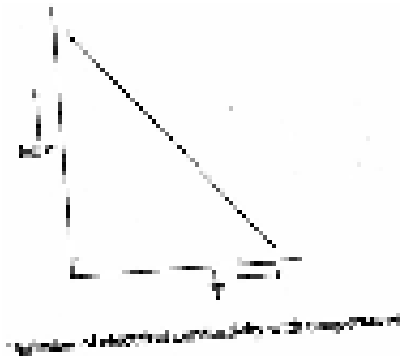
$$\sigma_i = n_i CT^{3/2}$$

Substituting for n_i from eq we get

$$\sigma_i = 2\left(\frac{2\mu RT}{h2}\right)^{3/2} CT^{3/2}(m_e^* m_h^*)^{3/4} \exp\left(\frac{-Eg}{2RT}\right)$$

$$\log \sigma_i = \log x - \frac{Eg}{2RT}$$

A graph of $\log \sigma_i$ Vs 1/T gives a straight line shown in fig below:



LIFE TIME OF MINORITY CARRIER:

In Semiconductor devices electron and hole concentrations are very often disturbed from their equilibrium values. This may happen due to thermal agitation or incidence of optical radiation. Even in a pure Semiconductor there will be a dynamic equilibrium. In a pure Semiconductor the number of holes is equal to the number of free electrons. Thermal agitation continuously produces of new EHP per unit volume per second while other EHP disappear due to recombination. On the average a hole exists for a time period of Tp while an electron exists for a time period Tn before recombination take place. This time is called the mean life time. If we are dealing with holes in an n-type Semiconductor, Tp is called the minority carrier life time. These parameters are important in Semiconductor devices as they indicate the time required for electron and hole concentration to return to their equilibrium values after they are disturbed.

Let the equilibrium concentration of electrons and holes in an n-type Semiconductor be n_0 and p_0 respectively. If the specimen is illuminated at $t = t_i$, additional EHP_S are generated throughout the specimen. The existing equilibrium is disturbed and the new equilibrium concentrations are $\bar{p}$ and $\bar{n}$. The excess concentration of holes = $\bar{p} - p_0$ – Excess concentration of electrons = $\bar{n} - n_0$ Since the radiation creates EHP_S.

$$p - p_0 = n - n_0$$

Due to incident radiation equal no of holes and electrons are created. How ever, the percentage increase of minority carriers is much more than the percentage of majority carries. In fact, the majority charge carrier change is negligibly small. Hence it is the minority charge carrier density that is important. Hence, we shall discuss the behaviour of minority carriers.

As indicated in radiation is removed at t = 0. Let us investigate how the minority carrier density returns to its original equilibrium value.

The hole concentration decreases as a result of recombination. Decrease in hole concentration per second due to recombination = p/T_p. But the increase in hole concentration per second due to thermal generation = g Since charge can neither be created nor destroyed

$$\frac{dp}{dt} = g - \frac{p}{T_p}$$

When the radiation is with drawn, the hole concentration p reaches equilibrium value p_0 Hence g = p0/Tp. Then eqn may be rewritten as

$$\frac{dp}{dt} = \frac{p_0 - p}{T_p}$$

We define excess carrier concentration. Since p is a function of time.

$$p' = p - p_0 = p'(t)$$

from we may write $\frac{dp}{dt} = \frac{-p'}{T_p}$

The solution to the above differential equation is given by

$$p'(t) = p(0)\, e^{-t/Tp}$$

The excess concentration decreases exponentially to zero with a time constant T_p.

DRIFT CURRENT:

In an electric field E, the drift velocity V_d of carriers superposes on the thermal velocity V_{th}. But the flow of charge carriers results in an electric current, known as the drift current. Let a field E be applied, in the positive creating drifts currents J_{nd} and J_{pd} of electrons and holes respectively.

Without E, the carriers move randomly with rms velocity V_{th}. Their mean velocity is zero. The current density will be zero. But the field E applied, the electrons have the velocity V_{de} and the holes V_{dh}.

Consider free electrons in a Semiconductor moving with uniform velocity Vde in the negative x direction due to an electric field E. Consider a smaller rectangular block of AB of length V_{de} inside the Semiconductor. Let the area of the side faces each be unity. The total charge Q in the elements AB is

Q = Volume of the element x density of partially change on each particle
= (V_{de} x 1x 1) x n x –q
Thus Q = -qnV_{de}

Where n is the number density of electrons. The entire charge of the block will cross the face B, in unit time. Thus the drift current density Jnd due to free electrons at the face B will be.

$$J_{nd} = - q\, nV_{de}$$

Similarly for holes $J_{pd} = q\, nV_{dh}$

but $\mathbf{V_{de} = -\mu_n E}$

and $V_{dh} = \mu_p E$

hence $J_{nd} = n\, q\mu_n E$

and $J_{pd} = p\, q\mu_n E$

The total drift current due to both electrons and holes J_d is

$$J_d = J_{nd} + J_{pd} = (nq\mu_n + pq\,\mu_p)E$$

Even though electrons and holes move in opposite direction the effective direction of current flow, is the same for both and hence they get added up. Ohm's Law can be written in terms of electrical conductivity, as

$$J_d = \sigma E$$

Equating the RHS of eq we have

$$\sigma = nq\mu_n + pq\mu_p = \sigma_n + \sigma_p$$

For an intrinsic Semiconductor $n = p = n_i$

$$\sigma_i = n_i\, q(\mu_n + \mu_p)$$

DIFFUSION CURRENTS:

1. Diffusion Current: Electric current is Setup by the directed movement of charge carriers. The movements of charge carriers could be due to either drift or diffusion. Non-uniform concentration of carriers gives rise to diffusion. The first law of diffusion by Fick States that the flux F, i.e., the particle current is proportional and is directed to opposite to the concentration gradient of particles. It can be written mathematically, in terms of concentration N, as

$$F = -D\, \nabla N$$

Where D stands for diffusion constant.

In one dimension it is written as

$$F = -D \frac{\partial N}{\partial x}$$

In terms of Je and Jp the flux densities of electrons holes and their densities n and p respectively.

We get $J_e = -D_n \frac{\partial N}{\partial x}$

and $J_n = -D_p \frac{\partial p}{\partial x}$

Where D_n and D_p are the electron and hole diffusion constant constants respectively. Then the diffusion current densities become

$$J_n \text{ diff} = q D_n \frac{\partial N}{\partial x}$$

$$J_p \text{ diff} = - q D_p \frac{\partial p}{\partial x}$$

THE EINSTEIN RELATIONS:

When both the drift and the diffusion currents are present total electron and hole current densities can be summed up as

$$J_n = J_{nd} + J_n \text{ diff}$$

$$J_n = nq\mu_n E + qD_n \frac{\partial n}{\partial x}$$

$$J_p = pq\mu_p E - qD_p \frac{\partial p}{\partial x}$$

Now, let us consider a non uniformly doped n-type slab of the Semiconductor fig shown below (9) under thermal equilibrium. Let the slab be intrinsic at x = 0 while the donor concentration, increases gradually upto x = 1, beyond which it becomes a constant. Assume that the Semiconductor is non-degenerate and that all the donors are ionized. Due to the concentration gradient, electrons tend to diffuse to the left to x = l. This diffusion leaves behind a positive charge of ionized donors beyond x = 1 and accumulates electron near x = 0

plane. This charge imbalance. Sets up an electric field in which the electrons experience fill towards x = 1.

Fig shows illustrates the equilibrium potential $\phi(x)$ fig shown refers to the bond diagram of the Semiconductor.

Both E1 and EF coincide till x = 0 when n0 = ni that EF continues to be the same throughout the slab. But since the bond structure is not changed due to doping, the bond edges bond with equal separation all along. How ever, the level Ei continues to lie midway between EV and E.

In thermal equilibrium, the electrons tend to diffuse down the concentration tending to setup a current from the right to left. The presence of electric field tends to set up drift current of electrons in the opposite direction. Both the currents add upto zero. Thus we obtain

$$J_n = qD_n \frac{\partial n}{\partial x} + nq\mu_n E = 0$$

$$\text{i.e.,} \quad D_n \frac{\partial n}{\partial x} + n\mu_n E = 0$$

For a non degenerate Semi conductor.

$$n(x) = n_i \exp \frac{E_F - E_i(x)}{RT}$$

Thus relation is valid at all points in the Semiconductor further. The electronic concentration is not influenced by the small in balance of charge. Energy is defined in terms of $\phi(x)$ the potential.

$$E(x) = -q\phi(x)$$

Then $E_F - E_i(x) = E_i(0) - E_i(x) = -q[\phi(0) - \phi(x)]$

$$= q\phi(x)$$

Assuming $\phi(0) = 0$ we get $n(x) = n_i \exp \frac{q\phi(x)}{RT}$

$$\frac{dn}{} \quad -d\phi$$

Substituting ------ from eqn along with E = ----- we get

$$\frac{dx}{} \qquad \frac{dx}{}$$

$$D_n \frac{nq}{RT}\frac{d\phi}{dx} = \mu_n\, n \frac{d\phi}{dx}$$

Simplifying we obtain, $D_n = \frac{RT}{q}\mu_n$

Simplifying for holes $D_p = \frac{RT}{q}\mu_p$

These are known as Einstein relations and the factor (RT/q) as thermal voltage. The above relations hold good only for non degenerate Semiconductors. For the degenerate case the Einstein's relations are complex.

It is clear from the Einstein's relation that Dp μp and Dn,μn are related and they are functions of temperature also. The relation of diffusion constant D and the mobility μ confirms the fact, that both the diffusion an drift processes arise due to thermal motion and scattering of free electrons, even though they appear to be different.

EQUATION OF CONTINUITY:

If the equilibrium concentrations of carriers in a Semiconductor are disturbed, the concentrations of electrons and holes vary with time. How ever the carrier concentration in a Semiconductor is a function of both time and position.

The fundamental law governing the flow of charge is called the continuity equation. It is arrived at by assuming law to conservation of charge provided drift diffusion and recombination processes are taken into account.

Consider a small length Δx of a Semiconductor sample with area A in the Z plane fig shown above. The hole current density leaving the volume (ΔxΔ) under consideration is Jp (x + Δx) and the current density entering the volume is Jp(x). Jp (x + Δx) may be smaller or

larger than Jp(x) depending upon the generation and recombination of carriers in the element. The resulting change in hole concentration per unit time.

∂p = hole flux entering per unit time – hole flux leaving per unit

$$\frac{\partial p}{\partial t}_{x \to x+\Delta x} = Jp(x) - \frac{Jp(x+\Delta x)}{q\,\Delta x} - \frac{\delta p}{Tp}$$

Where Tp is the recombination life time. According to eqn, the rate of hole build up is equla to the rate of increase of hole concentration remains the recombination rate. As Δx approaches zero, we may write

$$\frac{\partial p}{\partial t}(x,t) = \frac{\partial\, \delta p}{\partial t} = \frac{-1\, \partial\, Jp}{q\ \partial x} - \frac{\delta p}{Tp}$$

The above is called the continuity equation for holes for electrons

$$\frac{\partial \delta n}{\partial t} = \frac{1\ \partial J_n}{q\ dx} - \frac{\delta n}{Tn}$$

If there is no drift we may write

$$J_n(diff) = qD_n \frac{\partial \delta}{\partial x}$$

Substituting the above eqn we get the following diffusion eqn for electrons.

$$\frac{\partial \delta n}{\partial t} = D_n \frac{\partial^2 \delta n}{\partial x^2} - \frac{\delta n}{T_n}$$

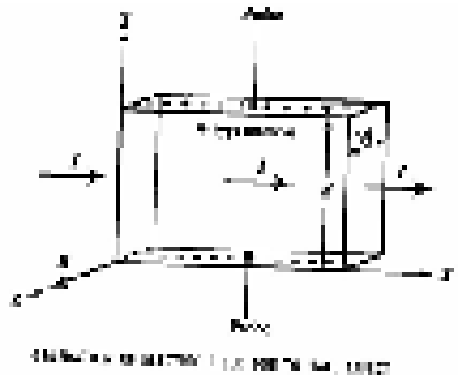
For holes we may write

$$\frac{\partial \delta p}{\partial t} = D_p \frac{\partial^2 \delta p}{\partial x^2} - \frac{\delta p}{T_p}$$

HALL EFFECT:

When a material carrying current is subjected to a magnetic field in a direction perpendicular to the direction of current, an electric field is developed across the material in a direction perpendicular to both the direction of the magnetic field and the current direction. This phenomenon is called Hall Effect.

Hall Effect finds important application in studying the electron properties of semi conductor, such as determination of carrier concentration and carrier mobility. It also used to determine whether a semi conductor is n-type, or p- type.



THEORY:

Consider a rectangular slab of an n-type Semiconductor carrying current in the positive x-direction. The magnetic field B is acting in the positive direction as indicated in fig above. Under the influence of the magnetic field, electrons experience a force F_L given by

$$F_L = - Bev \quad \text{---------- (1)}$$

Where e = magnitude of the charge of the electron

v = drift velocity

Appling the Fleming's Left Hand Rule, it indicates a force F_H acting on the electrons in the negative y-direction and electron are deflected down wards. As a consequence the lower face of the specimen gets negatively charged (due to increases of electrons) and the upper face

positively charged (due to loss of electrons). Hence a potential V_H, called the Hall voltage appears between the top and bottom faces of the specimen, which establishes an electric field E_H, called the Hall field across the conductor in negative y-direction. The field E_H exerts an upward force F_H on the electrons. It is given by

$$F_H = - eE_H \quad \text{----------(2)}$$

F_H acts on electrons in the upward direction. The two opposing forces F_L and F_H establish an equilibrium under which

$$|F_L = F_H$$

using eqns 1 and 2 $\quad -Bev = -eE_H$

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

If 'd' is the thickness of the Specimen

$$E_H = \frac{V_H}{d}$$

$$V_H = E_H\, d = Bvd \quad \text{from eqn (3)---------- 4}$$

If ω is the width of the specimen in z- direction.

The current density

$$J = \frac{I}{\omega d}$$

But $J = nev = \rho v$ ---------- 5

Where n = electron concentration

And ρ = charge density

$$\therefore \quad \rho v = \frac{I}{\omega d}$$

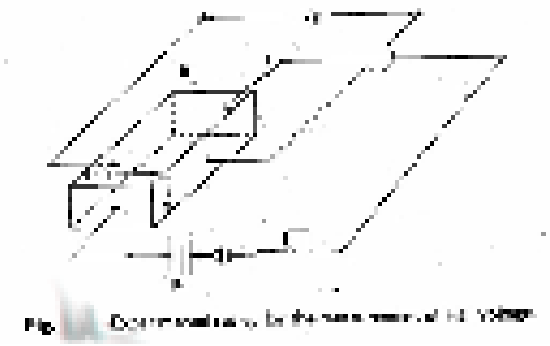
$$v = \frac{I}{\rho\omega d} \quad \text{---------- 6}$$

Substitutinf for v, from eqns 6 and 4

$$V_H = BI / \rho\omega$$

$$\rho = \frac{BI}{V_H \omega}$$

Thus, by measuring V_H, I, and ω and by knowing B, the charge density ρ can be determined.



Hall Coefficient:

The Hall field E_H, for a given material depends on the current density J, and the applied field B

i.e., $E_H \propto JB$

$$E_H = R_H JB$$

Where R_H is called the Hall Coefficient

Since $V_H = \frac{BI}{\quad}$

$$\rho\omega$$

$$E_H = \frac{V_H}{J\omega d}$$

$$J = \frac{I}{\omega d}$$

$$\frac{BI}{J\omega d} = R_H \frac{I}{\omega d} B$$

This leads to $R_H = \frac{I}{\rho}$

Mobility of charge carriers:

The mobility μ is given by $\mu = \frac{v}{E}$

But $J = \sigma E = nev = \rho v$

$\therefore \sigma E = \rho v$

$$\text{or } E = \frac{\rho v}{\sigma}$$

$$\Rightarrow \mu = \frac{\sigma}{\rho} = \sigma R_H \quad (\therefore 1/\rho = R_H)$$

σ is the conductivity of the semi conductor.

(C) Applications

(a) Determination of the type of Semiconductor: The Hall Coefficient R_H is negative for an n-type Semiconductor and positive for a p-type material. Thus, the sign of the Hall coefficient can be utilized to determine whether a given Semiconductor is n or p type.

(b) Determination of Carrier Concentration: Equation relates the Hall Coefficient RH and charge density is

$$R_H = \frac{1}{p} = -\frac{1}{ne} \text{ (for n-type}$$

$$= \frac{1}{pe} \text{ (for p-type}$$

$$\text{Thus } n = \frac{1}{eR_H}$$

$$\text{and } \frac{1}{eR_H}$$

(c) Determination of mobility: According to equation the mobility of charge carriers is given by

$$\mu = \sigma|R_H|$$

Determination of σ and R_H leads to a value of mobility of charge carriers.

(d) Measurement of Magnetic Induction (B):- The Hall Voltage is proportional to the flux density B. As such measurement of VH can be used to9 estimate B.