UNIT-IV

SEMICONDUCTORS AND MAGNETIC MATERIALS

Basic terms and definitions

Semiconductor	A semiconductor material is one whose electrical properties lie between that of insulators and good conductors.
Intrinsic semiconductor	A pure semiconductor free from any impurity is called intrinsic semiconductor.
Extrinsic semiconductors	Extrinsic semiconductors are formed by adding suitable impurities to the intrinsic semiconductor.
n-type semiconducutor	When pentavalent impurity is added to pure semiconductor, it results in n-type semiconducutor.
p-type semiconducutor	When trivalent impurity is added to pure semiconductor, it results in p-type semiconducutor.
Drift current	The drift current is due to the motion of charge carriers due to the force exerted on them by an electric field.
Diffusion current	Diffusion current is a current in a semiconductor caused by the diffusion of charge carriers (holes and/or electrons).
Hall effect	When a current-carrying semiconductor is kept in a magnetic field, the charge carriers of the semiconductor experience a force in a direction perpendicular to both the magnetic field and the current.
Direct band gap semiconductor	The top of the valence band and the bottom of the conduction band occur at the same value of momentum.
Indirect band gap semiconductor	The maximum energy of the valence band occurs at a different value of momentum to the minimum in the conduction band energy.
PN junction diode	The PN junction diode is a two terminal device, which is formed when one side of the PN junction diode is made with p-type and doped with the N-type material.
p–n junction	A p–n junction is a boundary or interface between two types of semiconductor materials,
Depletion region	Depletion region or depletion layer is a region in a P-N junction diode where no mobile charge carriers are present.
Magnetic materials	*Magnetic materials* are those *materials* that can be either attracted or repelled when placed in an external *magnetic* field and can be magnetized themselves.

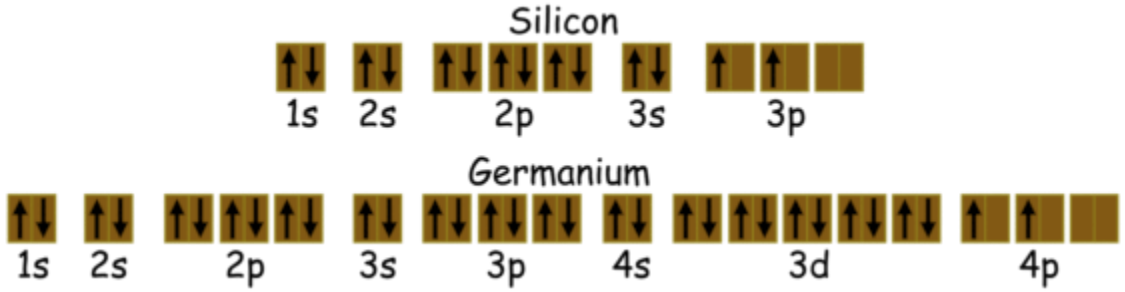
Magnetism	Magnetism is a force that acts at a distance due to a magnetic field.
Magnetic dipole moment	The product of the current flowing through the loop and the area of the loop. magnetic dipole moment
Magnetic field	A magnetic field is an area which is under the influence of a magnetic charge.
Magnetic field strength	The force experienced by a unit north pole placed at a given point In a magnetic field and is measured in amperes per meter (A/m)
Magnetisation	Magnetic moment per unit volume Units: (A/m)
Magnetic susceptibility	Ratio of magnetisation produced in a sample to the magnetic field strength. It has no units
Magnetic Flux density	*Magnetic Flux density* is the measure of the number of magnetic lines of force per unit of cross-sectional area. Units: W b / m 2(or) Tesla
Magnetic permeability	The magnetic permeability is defined as the property of the material to allow the magnetic line of force to pass through it Units: H/M
Magnetic permeability of free space	It is a measure of amount of magnetic lines of forces passing through the air medium Units: H/M
Relative permeability	*Relative permeability definition* asthe ratio of the permeability of a medium to that of free space
Bohr magneton	Bohr magneton (symbol μ_B) is a physical constant and the natural unit for expressing the magnetic moment of an electron caused by either its orbital or spin angular momentum. Value: $9.274 \times 10^{-24} Am^2$.
Diamagnetic materials	Diamagnetic materials are repelled by a magnetic field; an applied magnetic field creates an induced magnetic field in them in the opposite direction, causing a repulsive force. In contrast, paramagnetic and ferromagnetic materials are attracted by a magnetic field.
*Para*magnetic *materials*	*Para materials* are weakly attracted by an externally applied magnetic field, and form internal, induced magnetic fields in the direction of the applied magnetic field. Due to their spin, unpaired electrons have a magnetic dipole moment and act like tiny magnets.
Ferromagnetic materials	The ferromagnetic materials are those substances which exhibit strong magnetism in the same direction of the field, when a magnetic field is applied to it.
Anti ferromagnetic materials	The material with anti parallel magnetic moment of same magnitudes

Ferrimagnetic materials	The material with anti parallel magnetic moment of different magnitudes
Hysteresis	Lagging of the magnetization of a ferromagnetic material, such as iron, behind variations of the magnetizing field
Hysteresis loss	The energy lost as heat, which is known as the hysteresis loss, in reversing the magnetization of the material is proportional to the area of the hysteresis loop.
Retentivity	The magnetism remaining in the magnetic material, even when the magnetising field is reduced to zero is called residual magnetism. The power of retaining this magnetism is called the retentivity or remanence.
Coercivity	The force required to remove the residual magnetism from the material is called the coercive force or coercivity of the material.
Soft magnetic materials	Soft magnetic materials are those materials that are easily magnetised and demagnetised.
Hard magnetic materials	Hard magnets, also referred to as permanent magnets, are magnetic materials that retain their magnetism after being magnetised.

Concepts:

Intrinsic Semiconductor:

Semiconductor is a material whose conductivity lies in-between that of the conductors and the insulators. Semiconductors which are chemically pure, meaning free of impurities, are called **Intrinsic Semiconductors** or Undoped Semiconductor or i-type Semiconductor. The most common intrinsic semiconductors are Silicon (Si) and Germanium (Ge), which belong to Group IV of the periodic table. The atomic numbers of Si and Ge are 14 and 32, which yields their electronic configuration as $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^2$ and $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^2$, respectively.



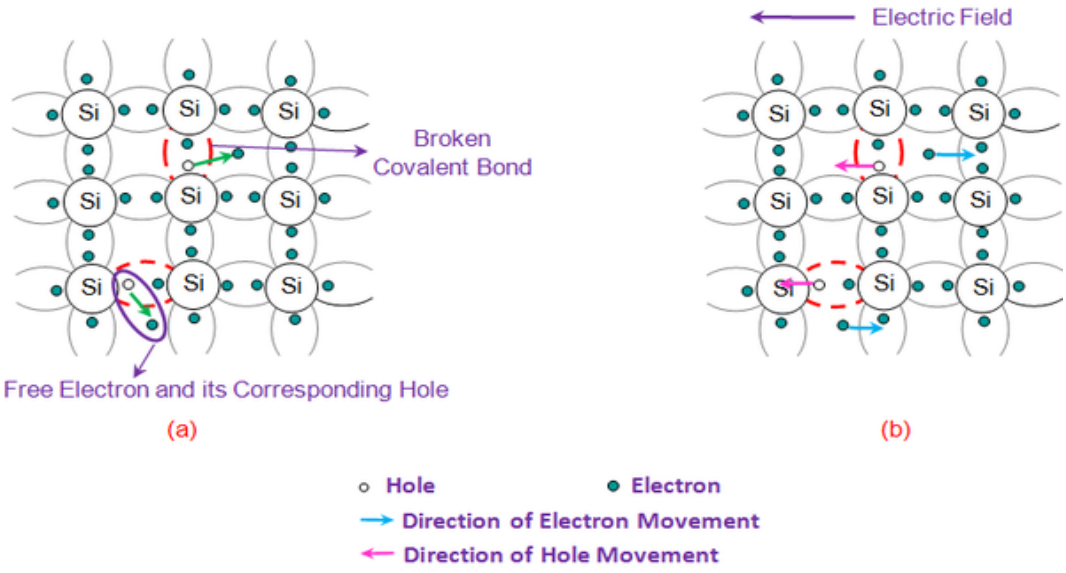


Figure 3 Conduction Mechanism in case of Intrinsic Semiconductors in the (a) Absence of Electric Field (b) Presence of Electric Field

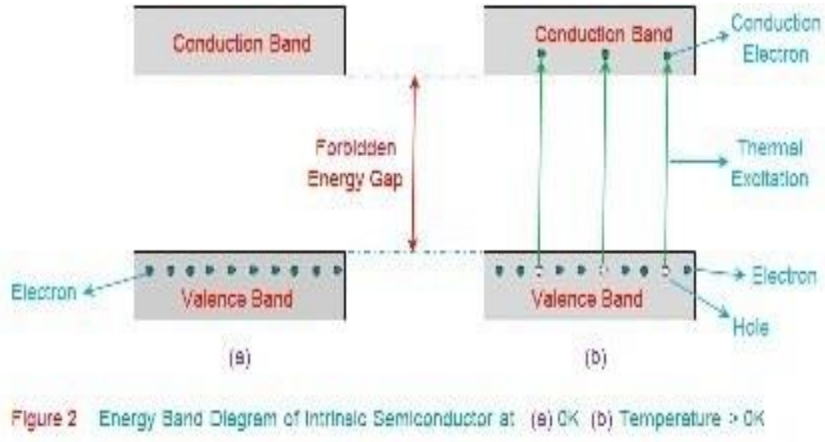


Figure 2 Energy Band Diagram of Intrinsic Semiconductor at (a) 0K (b) Temperature > 0K

In intrinsic semiconductors n=p

Extrinsic Semiconductor:

The process of adding impurities in minute quantities into the pure semiconductor material under controlled conditions is known as doping. The process is undertaken with the intention of increasing the conductivity of the material. Hence, the impurities are chosen in such a way that their addition into the pure semiconductor should increase the number of free charge carriers which can be either holes or electrons. These extrinsic semiconductors are of two types

1. N-type semiconductor
2. P-type semiconductor

1. N-type semiconductor: When a pentavalent impurity atom is added to the pure semiconductor then N-type semiconductor is formed.

$$n \rangle p$$

2. P-type semiconductor: When a trivalent impurity atom is added to the pure semiconductor then P-type semiconductor is formed.

$$p \rangle n$$

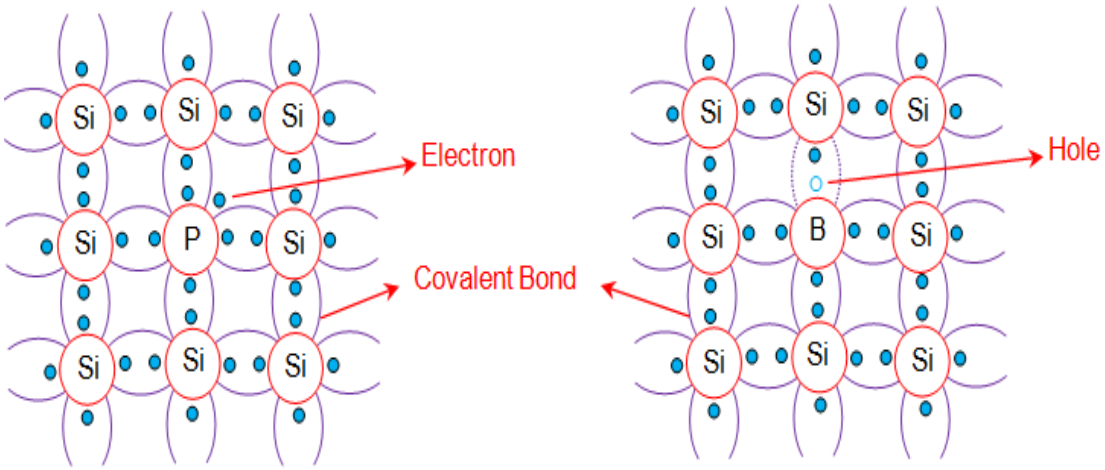


Figure 1 2-D Crystal Lattice of Silicon Doped with (a) Phosphorous (b) Boron

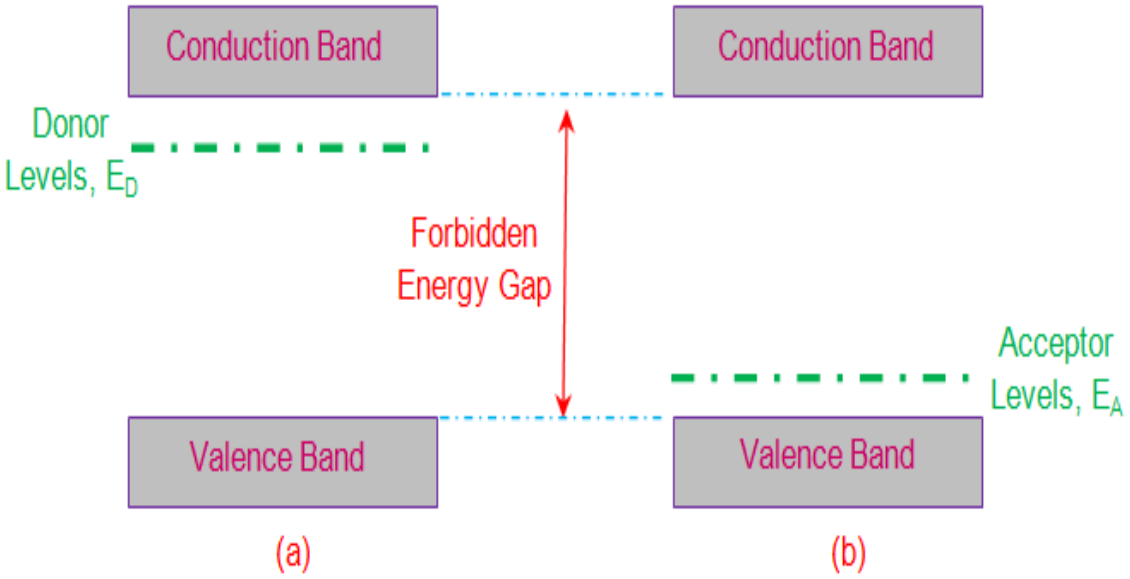
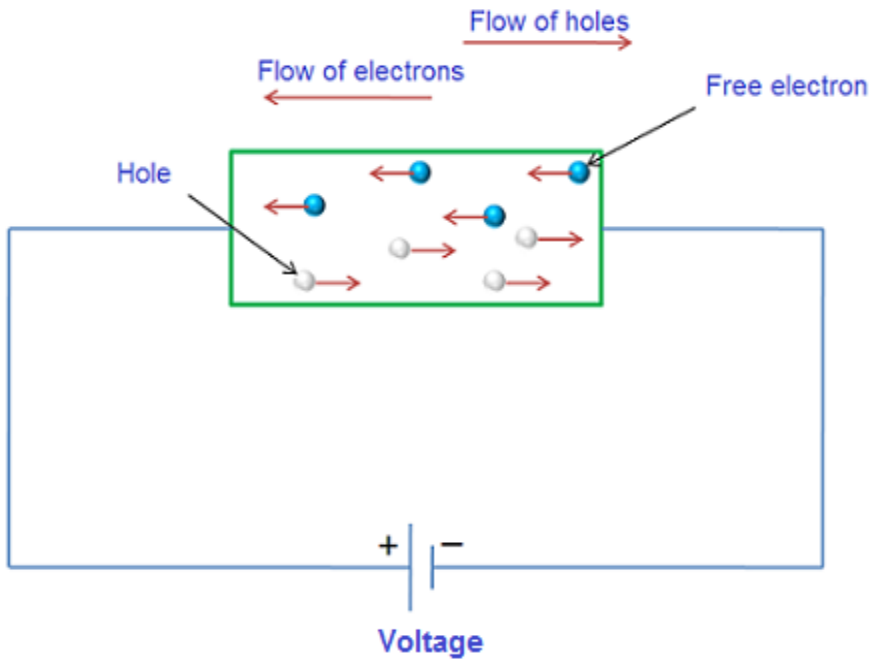


Figure 2 Energy Band Diagram of (a) *n*-type Extrinsic Semiconductor
(b) *p*-type Extrinsic Semiconductor

Drift current :

The flow of charge carriers, which is due to the applied voltage or electric field is called drift current.

In a semiconductor, there are two types of charge carriers, they are electrons and holes. When the voltage is applied to a semiconductor, the free electrons move towards the positive terminal of a battery and holes move towards the negative terminal of a battery.



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The drift current density due to free electrons is given by

$$J_n = e n \mu_n E$$

and the drift current density due to holes is given by

$$J_p = e p \mu_p E$$

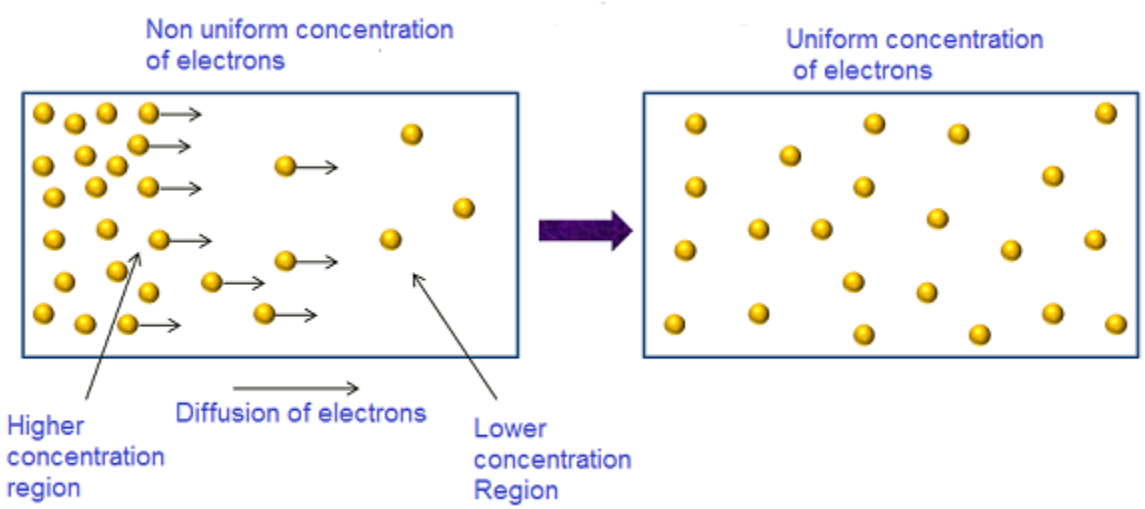
Where J_n = drift current density due to electrons
J_p = drift current density due to holes
e = charge of an electron = 1.602×10^{-19} Coulombs (C).
n = number of electrons
p = number of holes

Then the total drift current density is

$$J = J_n + J_p$$
$$= e n \mu_n E + e p \mu_p E$$
$$J = e (n \mu_n + p \mu_p) E$$

Diffusion current:

The process by which, charge carriers (electrons or holes) in a semiconductor moves from a region of higher concentration to a region of lower concentration is called diffusion. The current obtained due to the non-uniform distribution of charge carriers is known as Diffusion current.



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Concentration gradient:

The diffusion current density is directly proportional to the concentration gradient. Concentration gradient is the difference in concentration of electrons or holes in a given area. If the concentration gradient is high, then the diffusion current density is also high. Similarly, if the concentration gradient is low, then the diffusion current density is also low.

The concentration gradient for n-type semiconductor is given by

$$J_n \propto \frac{dn}{dx}$$

The concentration gradient for p-type semiconductor is given by

$$J_p \propto \frac{dp}{dx}$$

Where J_n = diffusion current density due to electrons

J_p = diffusion current density due to holes

Diffusion current density

The diffusion current density due to electrons is given by

$$J_n = +e\, D_n \frac{dn}{dx}$$

Where D_n is the diffusion coefficent of electrons

The diffusion current density due to holes is given by

$$J_p = -e\, D_p \frac{dp}{dx}$$

Where D_p is the diffusion co-efficent of holes

The total current density due to electrons is the sum of drift and diffusion currents.

J_n = Drift current + Diffusion current

$$J_n = en\mu_n E + e\, D_n \frac{dn}{dx}$$

The total current density due to holes is the sum of drift and diffusion currents.

J_p = Drift current + Diffusion current

$$J_p = ep\mu_p E - e\, D_p \frac{dp}{dx}$$

The total current density due to electrons and holes is given by

$$\mathbf{J = J_n + J_p}$$

Einstein's Relation:

The relation between mobility μ and diffusion coefficient D of charge carriers in a semiconductor is known as Einstein's Relation.

At equilibrium with no applied electric field, if the charge distribution is uniform, there is no net current flow. Any disturbance in equilibrium state leads to diffusion of charge carriers resulting in a diffusion current which creats an internal electric field. This field causes the drifting of charge carriers resulting in a drift current. At equilibrium condition, the drift current and diffusion current balance each other.

Let Δn be the excess electron concentration of a semiconductor. Then at equilibrium the drift and diffusion current densities due to excess electrons are equal

$\Delta neE\,\mu_n = eD_n \frac{\partial(\Delta n)}{\partial x}$ ---------- 1 Where E is internal electric field.

The force on excess electrons restoring equilibrium is equal to the product of excess charge and electric field i.e.,F=(Δn)eE

$$\frac{eDn}{\mu n}\frac{\partial(\Delta n)}{\partial x} \text{ ----------2}$$

From kinetic theory of gases,the force on gas molecule(charge carriers) is given by

$$F=K_BT\frac{\partial(\Delta n)}{\partial x} \text{ ----------3}$$

Comparing Equ 2 &3,we get

$$K_BT=\frac{eDn}{\mu n}$$

$$\frac{Dn}{\mu_n}=\frac{K_BT}{e}$$

Similarly for holes,we get

$$\frac{D_p}{\mu_n}=\frac{K_BT}{e}$$

therefore $$\frac{D_n}{\mu_n}=\frac{D_p}{\mu_p}$$

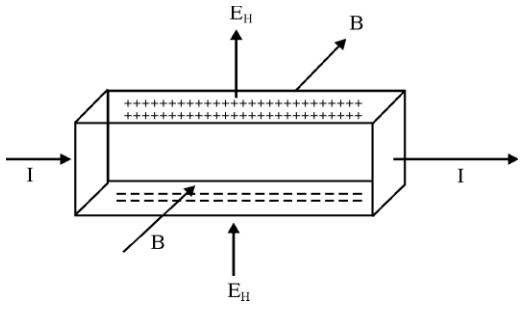
$$\boxed{\frac{D_n}{D_p}=\frac{\mu_n}{\mu_p}}$$

The above relation is known as Einstein's relation

Hall Effect

When conductor (metal or semiconductor) carrying a current is placed in a transverse magnetic field, an electric field is produced inside the conductor in a direction normal to both the current and the magnetic field. This phenomenon is known as "**Hall effect"** and the generated voltage is called "**Hall voltage".**

Fig 2.12 Hall effect



If a current carrying conductor placed in a perpendicular magnetic field, a potential difference will generate in the conductor which is perpendicular to both magnetic field and current. This phenomenon is called Hall Effect. In solid state physics, Hall effect is an important tool to characterize the materials especially semiconductors. It directly determines both the sign and density of charge carriers in a given sample. Consider a rectangular conductor of thickness ***t*** kept in XY plane. An electric field is applied in X-direction using Constant Current Generator (CCG), so that current ***I*** flow through the sample. If ***w*** is the width of the sample and ***t*** is the thickness. There for current density is given by

$$J_X = \frac{I}{bt} \qquad (1)$$

If the magnetic field is applied along negative z-axis, the Lorentz force moves the charge carriers (say electrons) toward the y-direction. This results in accumulation of charge carriers at the top edge of the sample. This set up a transverse electric field $\mathbf{E_y}$ in the sample. This develop a potential difference along y-axis is known as Hall voltage $\boldsymbol{V_H}$ and this effect is called Hall Effect.

A current is made to flow through the sample material and the voltage difference between its top and bottom is measured using a volt-meter. When the applied magnetic field B=0,the voltage difference will be zero.

We know that a current flows in response to an applied electric field with its direction as conventional and it is either due to the flow of holes in the direction of current or the movement of electrons backward. In both cases, under the application of magnetic field the magnetic Lorentz force, causes the carriers to curve upwards. Since the charges cannot escape from the material, a vertical charge imbalance builds up. This charge imbalance produces an electric field which counteracts with the magnetic force and a steady state is established. The vertical electric field can be measured as a transverse voltage difference using a voltmeter.

In steady state condition, the magnetic force is balanced by the electric force. Mathematically we can express it as $eE = evB$ (2)

Where 'e' the electric charge, 'E' the hall electric field developed, 'B' the applied magnetic field and 'v' is the drift velocity of charge carriers.

And the current 'I' can be expressed as, $I = neAv$ (3)

Where 'n' is the number density of electrons in the conductor of length l ,breadth 'b' and thickness 't'.

Using (1) and (2) the Hall voltage V_H can be written as,

$$V_H = \frac{IB}{net} \qquad (4)$$

by rearranging eq(4) we get $R_H = \frac{V_H t}{IB}$ (5)

Where R_H is called the Hall coefficient.

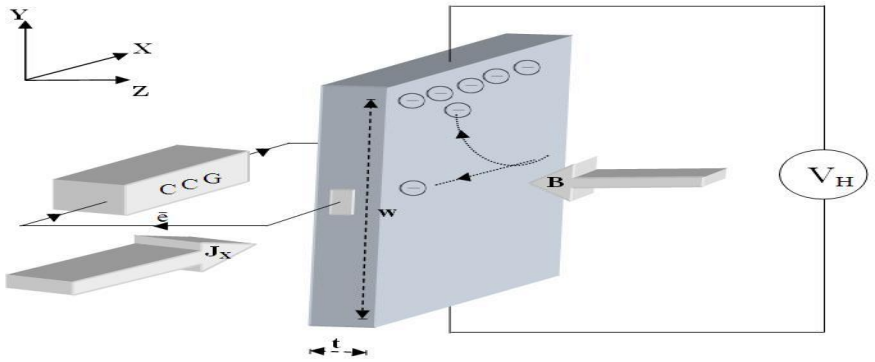
$$R_H = \frac{1}{ne} \quad (6)$$

$$\sigma = ne\,\mu_e \quad (7)$$

$$\mu_e = \frac{\sigma}{ne} \quad (8)$$

$$\mu_e = \sigma R_H \quad (9)$$

Diagram:



Applications of Hall Effect

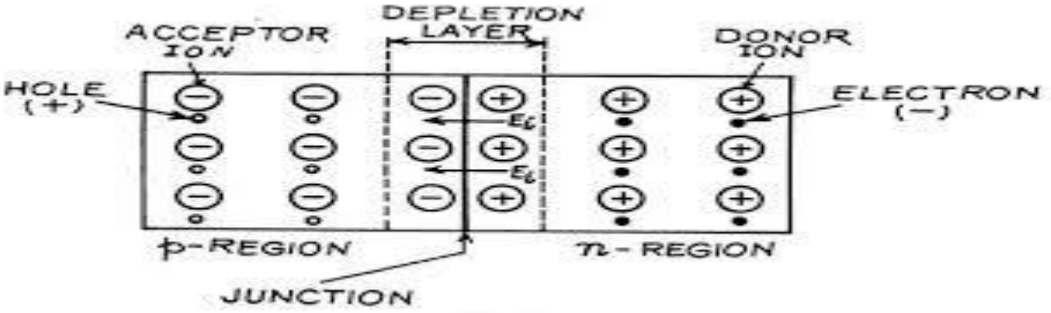
1. The sign (N-type (or) P-type) of charge carriers can be determined.
2. The carrier concentration can be determined
3. The mobility of charge carriers in measured directly
4. Electrical conductivity can be determined
5. It can be used to determine whether the given material is metal, insulator, or semiconductor and the type of the semiconductor.
6. It can be used to determine the power flow in an electromagnetic wave.

Working principle of p-n junction :

A P-N Junction Diode is formed by doping one side of a piece of silicon with a P-type dopant (boran) and the other side with a N-type dopant (phosphorus).Ge can be used instead of Silicon. The P-N junction diode is a two terminal device. This is the basic construction of the P-N junction diode. It is one of the simplest semiconductor devices as it allows current to flow in only one direction.The diode does not behave linearly with respect to the applied voltage, and it has an exponential V-I relationship.

p–n junction :

A p–n junction is a boundary or interface between two types of semiconductor materials, p-type and n-type, inside a single crystal of semiconductor.



If p-type semiconductor and n-type semiconductor of a diode are equally doped, and if the diode is forwardbiased, then holes will move toward the n-type semiconductor and electrons will move toward the p-typesemiconductor and they will diffuse with each other.

Depletion region :

Depletion region or depletion layer is a region in a P-N junction diode where no mobile charge carriers are present. Depletion layer acts like a barrier that opposes the flow of electrons from n-side and holes from p-side.

Potential barrier :

As more electrons and holes flow in the depletion region the number of positive and negative ions is reduced, causing the depletion region to narrow. The energy loss in overcoming the barrier potential results in a voltage drop across the PN junction equal to the barrier potential. (0.7V for Si, 0.3V for Ge.)

Forward bias:

When the positive terminal of the battery is connected to P-side and negative terminal to the N-side, so that the potential difference acts in opposite direction to the barrier potential, then the PN junction diode is said to be forward biased.

If a suitable positive voltage (forward bias) is applied between the two ends of the PN junction, it can supply free electrons and holes with the extra energy they require to cross the junction as the width of the depletion layer around the PN junction is decreased.

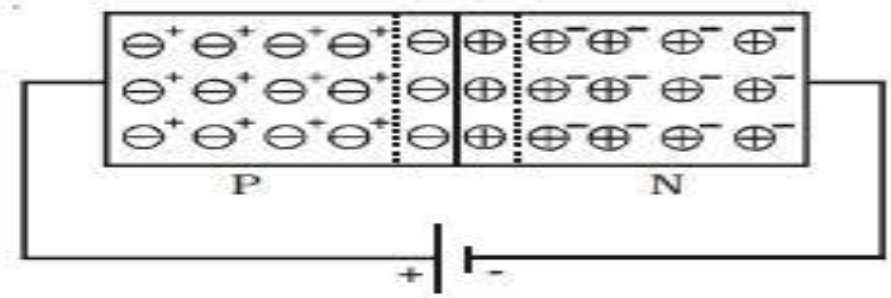


Fig Forward biased PN junction diode

Reverse bias :

Connecting the p-type region to the negative terminal of the battery and the n-type region to the positive terminal corresponds to reverse bias.

If the reverse biased voltage applied on the p-n junction diode , then even more number of free

electrons and holes are pulled away from the p-n junction. This increases the width of depletion region. ... Thus, the minority charge carriers carry the electric current in reverse biased p-n junction diode

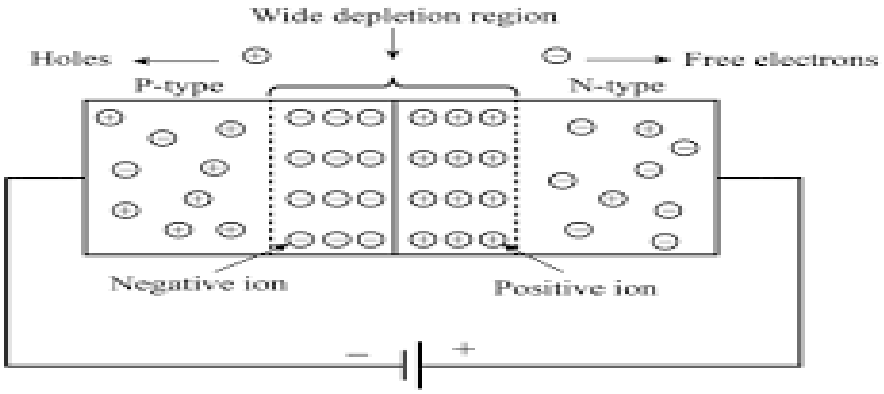
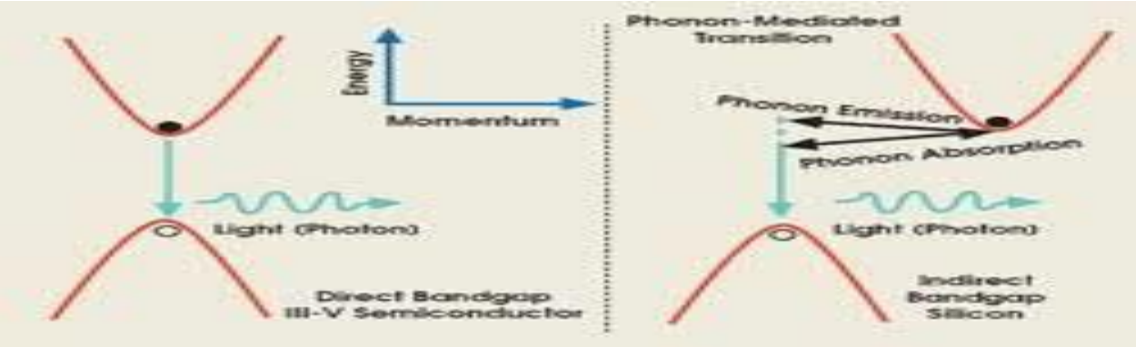


Figure 2

Differentiate between direct and indirect band gap semiconductors:

Direct band-gap (DBG) semiconductor	Indirect band-gap (IBG) semiconductor
1. A direct band-gap (DBG) semiconductor is one in which the maximum energy level of the valence band aligns with the minimum energy level of the conduction band with respect to momentum. 2. In a DBG semiconductor, a direct recombination takes place with the release of the energy equal to the energy difference between the recombining particles. 3. The probability of a radiative recombination is high. 4. The efficiency factor of a DBG semiconductor is higher. Thus, DBG semiconductors are always preferred over IBG for making optical sources. 5. Example, Gallium Arsenide (GaAs).	1. An Indirect band-gap (IBG) semiconductor is one in which the maximum energy level of the valence band and the minimum energy level of the conduction band are misaligned with respect to momentum. 2. In case of a IBG semiconductor, due to a relative difference in the momentum, first, the momentum is conserved by release of energy and only after the both the momenta align themselves, a recombination occurs accompanied with the release of energy. 3. The probability of a radiative recombination is comparatively low. 4. The efficiency factor of a IBG semiconductor is lower. 5. Example, Silicon and Germanium



MAGNETIC MATERIALS:

ORIGIN OF MAGNETIC MOMENT:

The macroscopic magnetic properties of a substance are a consequence of magnetic moments associated with individual electrons. Each electron in an atom has magnetic moments that originate from the following two sources

1. Orbital magnetic moment of electrons
2. Spin magnetic moment of electrons.
3. Nuclear magnetic moment

1. Orbital angular momentum

This corresponds to permanent magnetic dipole moments. Let us consider an electron describing a circular orbit of radius 'r' with a stationary nucleus at the centre as shown in Fig 3.3.(a). Let the electron rotate with a constant angular velocity of 'w' radians per second.

Electron revolving in any orbit may be considered as current carrying circular coil producing magnetic field perpendicular to its plane. Thus the electronic orbits are associated with a magnetic moment. The orbital magnetic moment of an electron in an atom can be expressed in terms of atomic unit of magnetic moment called Bohr Magnetron, defined as

The physical constant which represent this magnetic moment which is caused by either its orbital or spin angular momentum is called Bohr magneton. It is represented by the symbol μ_B .

In SI units it is defined by the equation

$$\mu_B = \frac{e\hbar}{2m_e}$$

In CGS unit it is defined by the equation

$$\mu_B = \frac{e\hbar}{2m_e c}$$

Here *e* represents the elementary charge, $\hbar$ represents reduced Planck's constant, m_e is the reduced mass of electron, and *c* represents speed of light.

The magnetic moment of electron is approximately equal to one Bohr magneton and the value of one Bohr magneton is equal to 9.274×10^{-24}J/T.

In order to derive the equation for Bohr magneton we consider an electron which moves around a circular having radius r with a velocity v.The time period for this orbit is given by the equation

$$T = \frac{2\pi r}{v}$$

Due to the motion of electron in circular orbit a current is developed given by

$$I = \frac{-ev}{2\pi r}$$

Here the magnetic moment is given by the equation

m =IA

Here, *A* is area of the circular loop.

$$\mu = IA$$

$$= \frac{-ev}{2\pi r} \times \pi r^2$$

$$= \frac{-erv}{2}$$

Divide and multiply by the mass of electron

$$\mu = \frac{-e}{2m_e} m_e vr$$

Here, $m_e vr$ *represents the angular momentum L*

$$\mu = \frac{-e}{2m_e} L \qquad .....(1)$$

For electron moving around circular orbit the angular momentum will be quantized given by the equation

$$L = \frac{nh}{2\pi}$$

Substituting value of L in (1) gives us the formula

$$\mu = \frac{-e}{2m_e} \times \frac{nh}{2\pi}$$

$$= -n\frac{eh}{4\pi m_e}$$

The quantity $\frac{eh}{4\pi m_e}$ *is called Bohr magneton (m_B)*

$$\mu_B = \frac{eh}{4\pi m_e}$$

$$= \frac{e\hbar}{2m_e}$$

$$= 9.27 \times 10^{-24} \text{ J/T}$$

Thus, value of Bohr magneton is equal to 9.274×10^{-24}J/T.

2. Electron spin magnetic moment

The magnetic moment due to spin of the electron isμ =eh/4πm
According to quantum theory the spin of electrons have only two possibilites +1/2 or -1/2.
Similar to eqn (3) we can write in the form
μ =(e/2m) S --(4)
where S is the spin quantum number here given by (1/2).(h/2π)
In short,

$\mu = g.(e/2m).S$ --(5)

Here g is the term known as g- factor.

When g=2, the spin contribution arises and when g=1 the orbital contribution arises.

3. Nuclear magnetic moment

The angular momentum associated with the nuclear spin is also measured in units of $h/2\pi$. The mass of the nucleus is larger than that of an e^- by the order of 10^3. Hence nuclear spin magnetic moment is of the order of 10^{-3} Bohr magnetrons.

Nuclear spin magnetic moment is given by

$\mu = eh/4\pi m_p$, Where m_p represents mass of proton

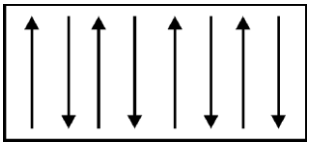
Classification of magnetic materials:

S. N	*Properties*	*Diamagnetic*	*Paramagnetic*	*Ferromagnetic*
1	Definition	It is a material in which there is no permanent magnetic moment.	It has permanent magnetic moment.	It has enormous (more) permanent magnetic moment.
2	Spin or magnetic moment or dipole alignment.	No spin alignment.	Random alignment	Parallel and orderly alignment.
3	Behavior	Repulsion of magnetic lines of force from the centre of the material.	Attraction of magnetic lines towards the centre.	Heavy attraction of lines of force towards the centre.
4	Magnetized direction	Opposite to the External magnetic field.	Same direction as the External magnetic field.	Same direction as the External magnetic field.
5	Permeability	It is very less	It is high	It is very high
6	Relativity permeability	$\mu_r < 1$	$\mu_r > 1$	$\mu_r >> 1$
7	Susceptibility	Negative	Low positive	High positive
8	Magnetic phase transition	At 0 K, diamagnetic material is Superconductor. When we increase its temperature it becomes a normal conductor.	When temperature is less than the curie temp, it is converted in to Diamagnetic.	When temperature of the material is greater than it Curie temperature it is converted into Paramagnet.

ANTIFERROMAGNETIC MATERIALS:

Definition:

In this material, the spins are aligned in anti-parallel manner due to unfavorable exchange interaction among them, resulting in zero magnetic moment. Even when the magnetic field is increased, it has almost zero induced magnetic moment.



Properties

1. It susceptibility is very small and it is positive.
2. The susceptibility is given by $\chi = C/T + T_N$ [where T_N –Neeltemp]
3. Initially, when the temperature increases, susceptibility value of the anti Ferro magnetic material also increases and reaches a maximum at a particular temperature this temperature called as **Neel temperature,** susceptibility decreases with increase in temperature and the material changes into paramagnetic material. (***Neel temperature*** - The temperature at which susceptibility is maximum is called Neel temperature).

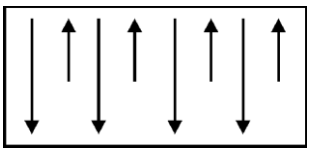
Examples : Ferrous oxide, $Fe\ Cl_4$, $Mn\ O_4$, MnS and some ionic compounds etc

FERRIMAGNETIC MATERIALS:

Definition

Ferrimagnetic materials or Ferrites are much similar to Ferromagnetic materials. The magnetic dipoles are aligned anti-parallel with unequal magnitudes. If small value of magnetic field is applied, it will produce the large value of magnetization.

Ferrimagnetic materials are widely used in high frequency applications and computer



memories.

1. The susceptibility is very large and positive and it is given by $\chi = C/T \pm T_c$
2. Beyond the Neel temperature susceptibility decreases.
3. These materials have low eddy current loss and low hysteresis losses.
4. ***Examples:*** Ferrous Ferrites and Nickel Ferrites

HYSTERESIS:

Hysteresis means "Lagging" i.e., The Lagging of intensity of magnetization (I) behind the intensity of magnetic field (H).

Experimental Determination

A graph is drawn between the **intensity of magnetization** [I] and the **intensity of magnetic field** [H], for a cycle of magnetization. The experimental setup consists of solenoid coil through which current is passed and the material is magnetized. By varying the value of current we can get different values of Intensity of magnetization [I] due to the magnetic field (H) in the solenoid. Here $H = n\,i\,l$

Where n – no of turns in the coil

l – length of the coil

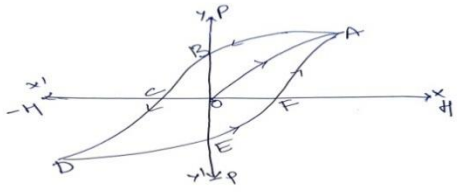
i – Current through the circuit.

In graph, OB = B_r = Retentivity, OC = H_C = Coercivity

1. When the intensity of magnetic field 'H' is increased from O to F, the value of Intensity of magnetization T if also increases from O to A, at 'A' the material reaches the saturation value of Intensity of magnetization.Then the value of I is constant.

2. When intensity of magnetic field 'H' is decreased from G to O, the value of Intensity of magnetization 'I' also decreases from A to B, but not to zero (0). Now the material retains [stores] some amount of magnetism known as **Retentivity,** even though the intensity of magnetic field 'H' is zero. It is represented as 'OB' in the graph.

3. When intensity of magnetic field 'H' is increased in reverse direction from O to C, the value of Intensity of magnetization 'I' decreases from B to C. i.e., the value of 'I' reaches zero.



4. The amount of intensity of magnetic field 'H' applied in the reverse direction to remove the **retentivity** is known as **Coercivity .o.Coercive force.** It is represented as 'OC' in thegraph.

5. Further repeating the process the remaining portion [CDEFA] in the graph is obtained. The closed loop [OABCDEFA] is called Hysteresis loop (or) (I – H) curve. For one cycle of magnetization.
6. Now the material is taken out. After a cycle of magnetization, there is some expenditure (loss) of energy.
7. This loss of energy is radiated in the form of heat energy in the material.
8. This loss of energy is directly proportional to the area of the loop.

Hysteresis loss

When the specimen is taken through a cycle of magnetization. There is a loss of energy in the form of heat. This loss of energy is known as Hysteresis loss.

HARD AND SOFT MAGENTIC MATERIAL:

In Hysteresis, after a cycle of magnetization, there is some expenditure (loss) of energy. This loss of energy is radiated in the form of heat energy in the material and it is directly proportional to the area of the loop. From the Hysteresis graph, we can select the soft and hard magnetic materials.

Hard Magnetic Materials

The materials which are very difficult to magnetize and demagnetize are called hard magnetic materials. These materials can be made by heating the magnetic materials and then cooling it **suddenly.** It can also be prepared by adding impurities.

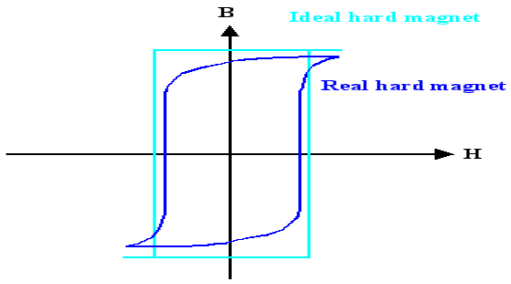


Fig.3.19 Hysteresis loop of a hard magnetic material

The above hysteresis loop is very hard and has a large loop area for a hard magnetic material, therefore the loss is also large. Domain wall does not move easily and require large value of H for magnetization. Its coercivity and retentivity values are large. Its eddy current loss is also high due to its low resistivity, the magnetostatic energy is large. It has low susceptibility and permeability. The hard magnetic materials have large amount of impurities and lattice defects.***Examples :*** *Tungsten steel, Carbon steel, Chromium steel, Alnico etc.,*

Properties

1) It is easilly magnetised and demagnetised.
2) They hysteresis area is very small and hence, the hysteresis loss is also small, as shownin figure.
3) The coercivity and rentenivity are very small.
4) These materials have large values of susceptibility and permeabilty.
5) Their magnetostatic energy is very small.
6) The eddy current loss is very small.

Applications

1) Iron-Silicon alloys are used in electrical equipment and magnetic cores of transformes.
2) Cast iron is used in the structure of electical machinery and the frame work of D.Cmachine.
3) Nickel alloys are used to manufacture inductors, relays and small motors.
4) It is also used for computer and data storage devices.

Soft Magnetic Materials

The materials which are easily magnetized and demagnetized are called soft magnetic materials. These materials can be made by **heating** the magnetic materials and then cooling it **slowly** to attain an ordered structure of atoms.

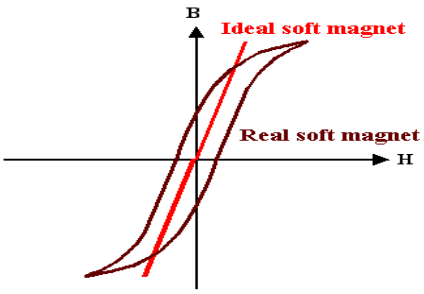


Fig.3.20 Hysteresis loop of a soft magnetic material

The above hysteresis loop is very small and has a less loop area for a soft magnetic materials. Therefore the loss is also small. Domain wall move easily and require small value of H for magnetization. Its coercivity and retentivity values are small, its eddy current loss is small due to its high resistivity. The magnetostatic energy is less, it has high value of susceptibility and permeability. The soft magnetic materials do not have impurities and lattice defects.

Examples: *Iron-Silicon alloys, Nickel-Iron alloys and Iron-cobalt alloys.*

Properties

7) It is very hard to magnetize and also demagnetize.
8) The hysteresis cure is very broad and has a large as shown in figure.
9) The coercivity and retentivity values are large.
10) These materials have low value of susceptibility and permeability.
11) The magnetostatic energy is large.
12) The eddy current loss is very high.

Applications

1) Magnets made by carbon steel are used for manufacturing the toys and compass needle.
2) Tungsten steel is used in making permanent magnets for D.C motors.
3) It is also used for making a small size of magnets.

Important Questions:

1. Write a note on bond and band theory of intrinsic and extrinsic semiconductors.
2. Describe the drift and diffusion currents in a semiconductor.
3. Derive their expressions and deduce Einstein relation.
4. Explain Hall effect and mention the applications of Hall effect.
5. Show that for n-type semiconductor the hall co-efficient $R_H = -\frac{1}{ne}$.
6. With theory explain the working principle of PN junction diode
7. Explain the origin of magnetic moment. Derive the value of Bohr magneton.
8. Distinguish between Dia,Para, ferro, anti ferro and ferri magnetic materials.
9. Explain the Hysteresis of Ferro magnetic materials.
10. Distinguish between soft and hard magnetic materials.