LECTURE NOTES

on

Basic Electronics engineering (Th.4 (b))

of 1st & 2nd semester

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CHAPTER-1

1. ELECTRONIC DEVICE

1.1 Basic Concept of Electronics and its application.

Defination:

The branch of engineering which deals with current conduction through a vacuum or gas or semiconductor is known as electronics.An electronic device is that in which current flows through a vacuum or gas or semiconductor.

(Or)

Electronics is the branch of science that deals with the study of the flow of electrons and their effects in a vacuum, gases, and semiconductor materials.

Applications:

Electronics has gained much importance due to its numerous applications in our daily life starting from home to any industry. For simplification we categorise them in some area such as

- **Consumer Electronics.**

  Electronics devices which make our life easy and better such as air conditioner, cooking appliances, dryer, personal computer, mobile phones, etc.

- **Commercial applications.**

  Electronic devices and gadgets are widely used for the commercial purpose such as Telephone, Airconditioning, heating, Digital Advertising, power supplies, Personal computer, MP3s, office equipment, light dimmer, uninterruptible power supplies (UPS), etc.

- **Medical applications.**

  With the advancement of the electronics field, and particularly that of computer technology has made possible many of the application which made possible for nurses and doctors to examine his patient. Many machines like NMR, ECE, x-ray, etc use electronics. There is noticeable advancement of electronics in the field of medical sciences. There are a few mindblowing innovations which prove how important is electronics – Robotic Arm, Robotic Check-Ups, Bionic Eye, Needle-Free Diabetes Care, etc.

- **Agriculture application.**

  Electronics has proved to be the biggest problem solver in the agriculture field. Today number of electronics devices and sensors are used to monitor a crop or enhance the production of Agriculture. Like e-Agri Sensors and other electronic gadgets which are used for measuring the salinity of soil, moisture level, and nutrition level in the soil.

- **Industrial automation.**

  Electronics applications are widely utilized in Arc and Industrial furnaces such as blowers, fans, pumps and compressors, industrial lasers, transformer tap changers, rolling mills, textile mills, excavators, cement mills, welding. Nowadays most of the firms use robotics technology Such as in the manufacturing of cars.

- **Communication.**

  In order to communicate for far distance, Electronic devices and systems are used such as Am Radio, FM Radio, Television, processing, Memory storage, display, analysis, protection, etc.

- **Military &defence applications.**

  Electronics devices and machinery are also widely used in the military such as UAV and drones which are used in the military for aerial attack as well as for monitoring. Magnetic anomaly detector, People sniffer, Night vision device, infrared detector, RADAR, PNS Hameed, and night vision camera etc. are some gadgets used by the military.

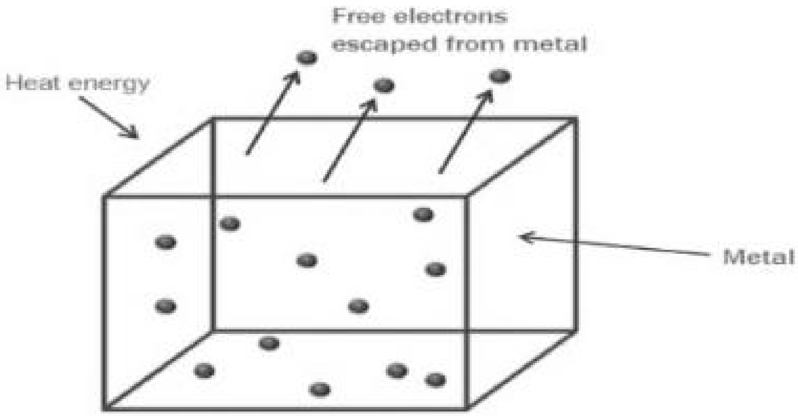
- **Automobiles.**

  Electronics are used in road vehicles, such as Lighting system of the car, telematics, in-car sound systems, etc. Initially, electronics were used to in cars to control engines. Nowadays almost every things are controlled using electronics whether it's a chair in car or speed limitation in car, or Gas management in the car. Now electronic with its advancement.

- **Aerospace.**

  Today with advancement in electronics engineering application in the field of aerospace has open many impossible ways to humans. Most of the parts used in the Space shuttle, Satellite power supplies, aircraft power management, and other communication instruments are electronics devices. Even in commercial airlines, there are numerous electronic devices which are used to measure different physical parameters like humidity, temperature, pressure, elevation, etc.

1.2 Basic Concept of Electron Emission & its types.



Electron emission is defined as the liberation of electrons from any surface of a substance.

Any metal consists of plenty of free electrons. Even at room temperature, these free electrons moves randomly inside the metal from one atom to another but can not leave the surface of the metal to provide electron emission.

This is because the free electrons reach the extreme boundary of the metal are pulled back by the positive nuclei behind them & their kinetic energy decreases.

Thus at the surface of a metal, a free electron encounters forces that prevent it to leave the metal. In other words, the metallic surface offers a barrier to free electrons and isknown as surface barrier.

However, if sufficient external energy is given to the free electron, its kinetic energy is increasedand thus electron will cross over the surface barrier to leave the metal. This additional energy requiredby an electron to overcome the surface barrier of the metal is called work function of the metal.

The amount of additional energy required to emit an electron from a metallic surface is known as work function of that metal.

Types of Electron Emission.

The process of emission happens by supplying Energy equal to or greater than the work function to the metal & the electron absorbs the energy, thus able toovercome the surface barrier and leaves the metal surface. Depending on the process of supplying external energy to the metal surface, the emission is of different types.

(i)Thermionic Emission.

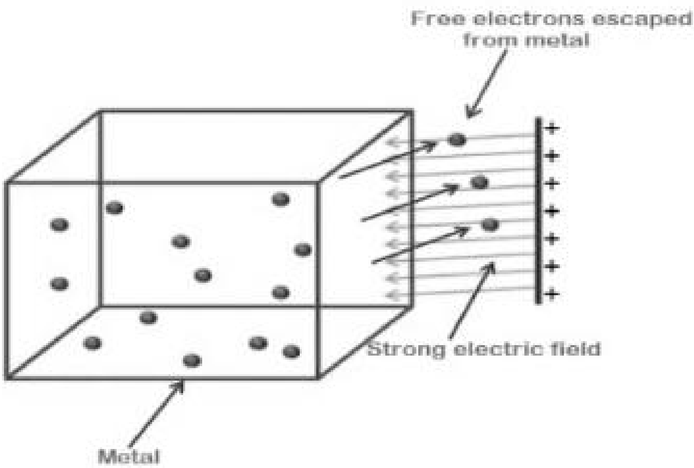
The process of electron emission from a metal surface by supplying thermal energy to it is known asthermionic emission.

In this method, the metal is heated to sufficient temperature (about2500ºC) to enable the free electrons to leave the metal surface. The number of electrons emitteddepends upon the temperature. The higher the temperature, the greater is the emission of electrons.This type of emission is employed in vacuum tubes.

(ii) Field emission.

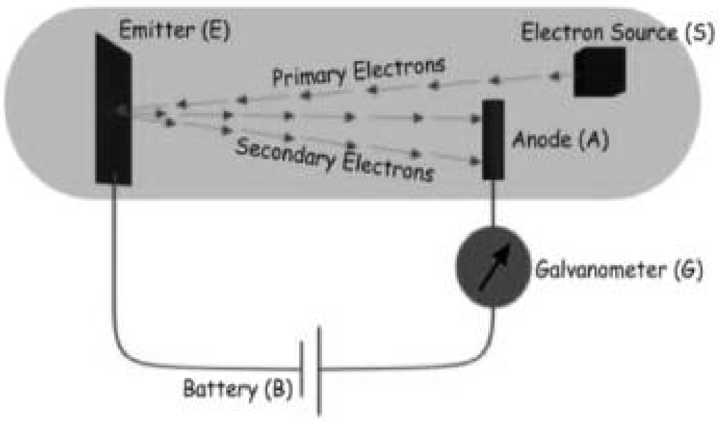
The process of electron emission by the application of strong electric field at the surface of a metal is known as field emission.

In this method, when a sufficiently high positive charge is placed in front of the emitter surface, due to the strong electrostatic force of the created electric field, the free electron can get sufficient energy to overcome the surface barrier and can get emitted from the surface of the emitter body. As this type of electron emission is caused by the electric field present in the space, it is called field emission. The stronger the electric field, the greater is the electron emission.



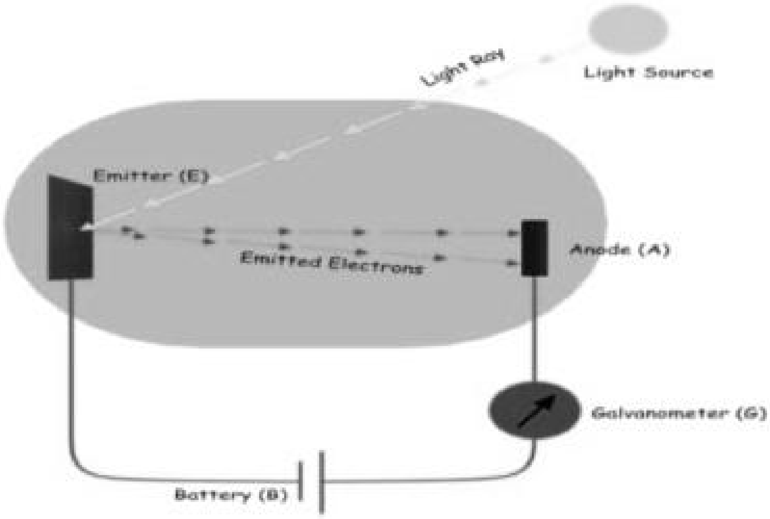
(iii) Secondary emission.

Electron emission from a metallic surface by the bombardment of high-speed electrons or other particles is known as secondary emission.



In this method, When a beam of high-velocity electrons sticks on the metal surface, the kinetic energy of high velocity striking electrons, transferred to the free electrons on the metal surface. Thus the free electrons may get sufficient kinetic energy to overcome the surface barrier and knocked out from the surface &start electron emission.

This type of emission is known as secondary electron emission.The electrons that strike the metal are called primary electrons while the emitted electrons are known as secondary electrons.



(iv) Photo-electric emission.

Electron emission from a metallic surface by the application of light is known as photo electric emission.

In this method, the energy of light falling upon the metal surfaceis transferred to the free electrons within the metal to enable them to leave the surface. The greater theintensity (i.e. brightness) of light beam falling on the metal surface, the greater is the photo-electricemission.

1.3 Classification of material according to electrical conductivity (Conductor, Semiconductor & Insulator) with respect to energy band diagram only.

For better understanding of classification we have to understand what is energy band and different types of bands present in a metal.

Energy Band: The range of energies possessed by an electron in a solid is known as **energy band.**

Valence band: The range of energies (i.e. band) possessed by valence electrons is known as **valenceband.**

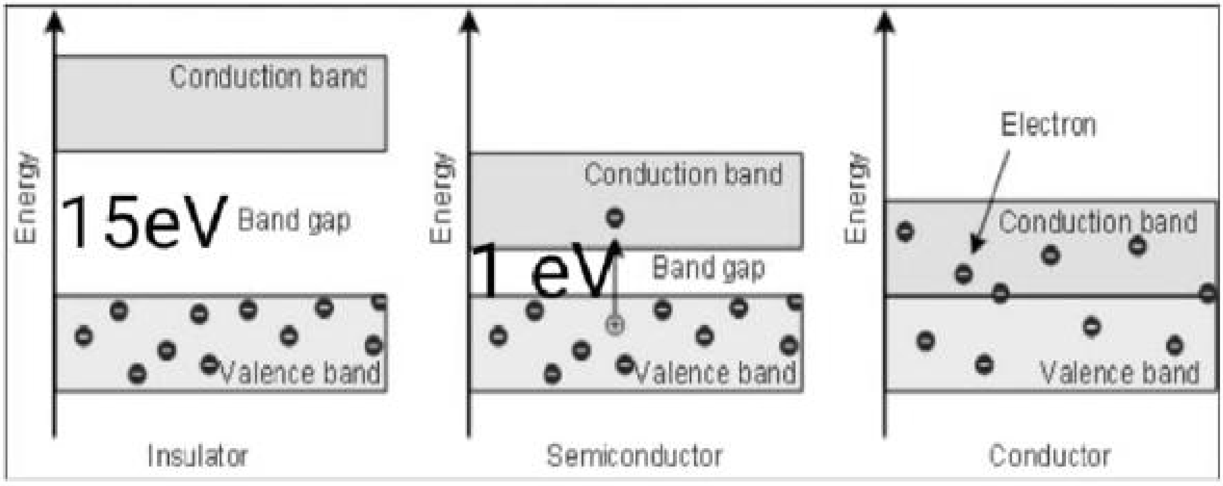
Conduction band: The range of energies (i.e. band) possessed by conduction band electrons is known as **conduction band.**

Forbidden energy gap: The separation between conduction band and valence band on the energy level diagram is known as **forbidden energy gap.**

(*i*) **Insulators.**Insulators (*e.g.* wood, glass etc.) are those substances which do not allow the passage of electric current through them. In terms of energy band, the valence band is full while the conduction band is empty. Further, the energy gap between valence and conduction bands is very large (15 eV). Therefore, a very high electric field is required to push the valence electrons to the conduction band.

However, when the temperature is raised, some of the valence electrons may acquire enough energy to cross over to the conduction band. Hence, the resistance of an insulator decreases with the increase in temperature *i.e.* an insulator has negative temperature coefficient of resistance.

(*ii*) **Conductors.**Conductors (*e.g.* copper, aluminium) are those substances which easily allow the passage of electric current through them. It is because there are a large number of free electrons available in a conductor. In terms of energy band, the valence and conduction bands overlap each other. Due to this overlapping, a slight potential difference across a conductor causes the free electrons to constitute electric current.



(*iii*) **Semicondutors.**Semiconductors (*e.g.* germanium, silicon etc.) are those substances whoseelectrical conductivity lies inbetween conductors andinsulators. In terms of energy band, the valence band isalmost filled and conduction band is almost empty.Further, the energy gap between valence and conductionbands is very small. Therefore,comparatively smaller electric field(smaller than insulators but much greater than conductors) isrequired to push the electrons from the valence band to the conduction band. In short, a semiconductorhas :

(***a***)almost full valence band

(***b***)almost empty conduction band

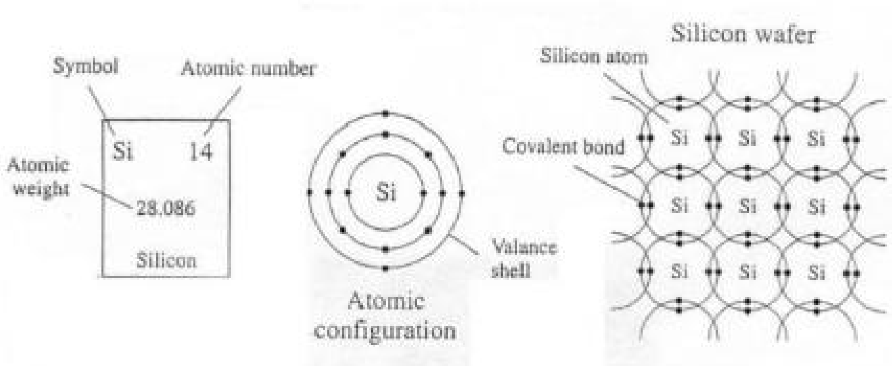
(*c*)small energy gap (1 eV) between valence and conduction bands.

At low temperature, the valence band is completely full and conduction band is completely empty. Therefore, a semiconductor virtually behaves as an insulator at low temperatures. However, even at room temperature, some electrons (about one electron for 1010 atoms) cross over to the conduction band, imparting little conductivity to the semiconductor.

1.4 Difference between Intrinsic & Extrinsic Semiconductor.

Intrinsic Semiconductor:

A semiconductor in an extremely pure form is known as an **intrinsic semiconductor**. In an intrinsic semiconductor, even at room temperature, hole-electron pairs are created. Whenelectric field is applied across an intrinsic semiconductor, the current conduction takes place by twoprocesses, namely; by *free electrons* and *holes*. The free electrons are produceddue to the breaking up of some covalent bonds by thermal energy. At the same time, holes arecreated in the covalent bonds. Under the influence of electric field, conduction through the semiconductoris by both free electrons and holes. Therefore, the total current inside the semiconductor is thesum of currents due to free electrons and holes.



Extrinsic Semiconductor:

When a small amount of impurity is added to a pure semiconductor it becomes**extrinsic semiconductor.**

The intrinsic semiconductor has little current conductivity at room temperature, to make it suitable for electronic applications we must change its conducting properties. This is achieved by adding a small amount of suitable impurity to a semiconductor. It is then called impurity or extrinsic semiconductor. The process of adding impurities to a semiconductor is known as doping.

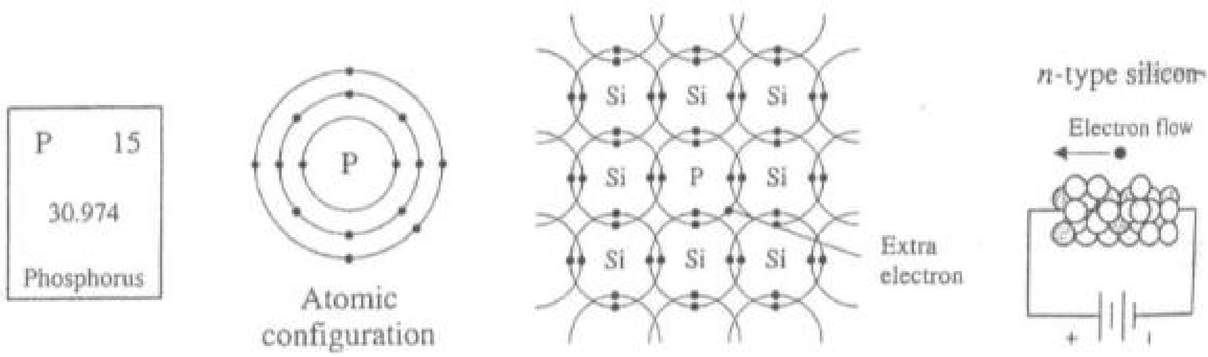
The purpose of adding impurity is to increase either the number of free electrons or holes in the semiconductor crystal. If a pentavalent impurity (having 5 valence electrons) is added to the semiconductor, a large number of free electrons are produced in the semiconductor. If a trivalent impurity (having 3 valence electrons) is added to the semiconductor, large number of holes are produced in the semiconductor crystal. Depending upon the type of impurity added, extrinsic semiconductors are classified into:

(i) n-type semiconductor **(ii)** p-type semiconductor

(i) n-type Semiconductor

When a small amount of pentavalent impurity is added to a pure semiconductor, it is known as n-type semiconductor.

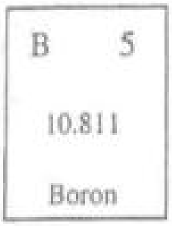
The addition of pentavalent impurity pro-vides a large number of free electrons in the semiconductor crystal. Typical examples of pentavalent impurities are arsenic, antimony,Bismuth and Phosphorous etc. Such impurities which produce n-type semiconductor are known as donor impurities because they donate or provide free electrons to the semiconductor crystal.In n-type semiconductor electrons are said to be the majority carriers whereas holes are the minority carriers.

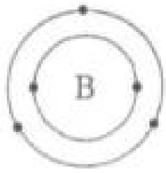


(ii) p-type Semiconductor

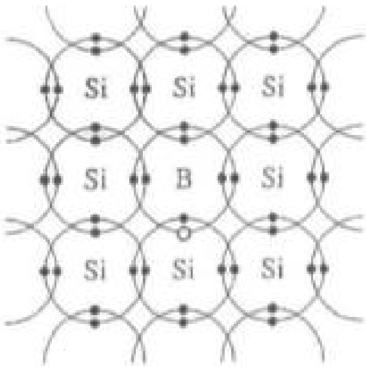
When a small amount of trivalent impurity is added to a pure semiconductor, it is called p-type Semiconductor.

The addition of trivalent impurity provides a large number of holes in the semiconductor. Typical examples of trivalent impurities are gallium, indium, boron etc. Such impurities which produce p-type semiconductor are known as acceptor impurities because the holes created can accept the electrons. In p-type semiconductor holes are the majority carriers whereas electrons are said to be the minority carriers.

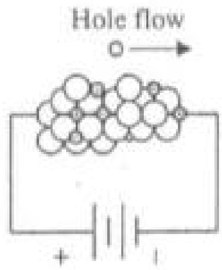




Atomic configuration



p-type silicon



Difference between Intrinsic & Extrinsic Semiconductor.

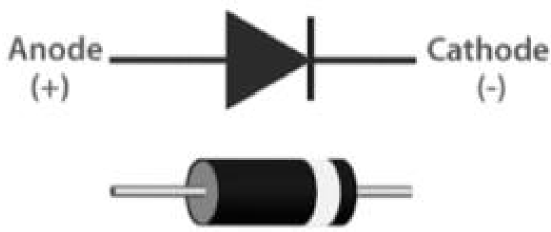
S.No	Intrinsic Semiconductor	Extrinsic Semiconductor
1.	Semiconductor in a pure form is called intrinsic semiconductor.	Semiconductor which are doped with impurity is called extrinsic semiconductor
2.	Here the change carriers are produced only due to thermal agitation.	Here the change carriers are produced due to impurities and may also be produced due to thermal agitation.
3.	They have low electrical conductivity.	They have high electrical conductivity.
4.	They have low operating temperature.	They have high operating temperature.
5.	At 0K, Fermi level exactly lies between conduction band and valence band.	At 0K, Fermi level exactly lies closer to conduction band in "n" type semiconductor and lies near valence band in "p" type semiconductor.
	Examples: Si,Ge,etc.	**Examples:** Si and Ge doped with Al, In,P,As etc

1.5 Difference between vacuum tube & semiconductor.

Vacuum tube	Semiconductor
• Power consumption is high and heat wastage is comparatively high	• Lower power consumption, less wastage of heat
• Large size than transistor	• Size is so small as compared to vacuum tubes.
• High cost.	• Low cost.
• Less suitable for portable products.	• Suitable for portable device.
• It requires the high voltage power supply, not suitable for smaller voltage devices.	• It requires a lower power supply, suitable for smaller voltage devices
• Low voltage gain	• High voltage gain
• There is glass tube in a vacuum tube so not that much physical strength.	• Physical strength is high
• Not that much depend upon temperature	• Depend upon Temperature
• High input impedance	• Low input impedance
• Made up of wires.	• Made up of PN junction.
• Vacuum tubes can easily be replaced by a user	• Relatively maintenance more difficult, cannot easily be replaced by a user.

1.6 Principle of working and use of PN junction diode, Zener diode and Light Emitting Diode (LED)

PN Junction:

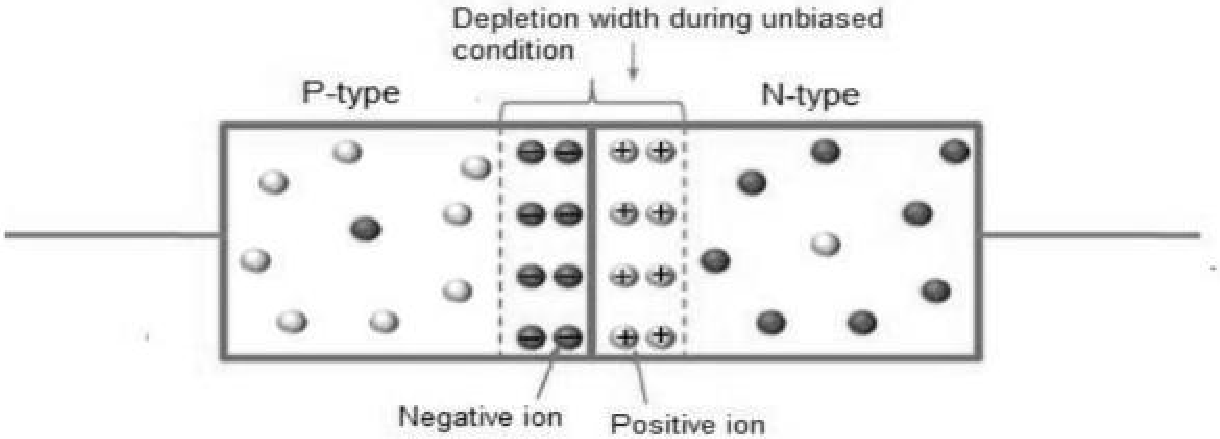


When a p-type & n-type semiconductor properly join together it forms pn junction. It is the basic building block for many semiconductor devices. After the formation of junction a large difference in carrier density exists which results holes in the p-side tends to diffuse into n-side leaving behind trivalent ion and electrons in the n-side are tends to diffuse into p-side leaving behind pentavalent ion. Due to this charg separation a layer of negative charges (trivalent ions) in p-type & positive charges (pentavalent ions) in n-type near the junction created.These two layers of positive and negative charges form the **depletion region**(or **depletion layer**).

Once pnjunction is formed and depletion layer created, the diffusion of free electrons stops. Inother words, the depletion region acts as a barrier to the further movement of free electrons across thejunction. Since the holes in p-side encounters a positive charge in n-side near the junction similarly electrons in n-side encounters a negative charge in p-side near the junction. The positive and negative charges set up an electric field. The electric field is a barrier to the free electrons in the n-region. There exists a potential difference across the depletion layer and is called **barrier potential** (V0).

Pn- junction Diode:

A pn junction is known as a semi-conductor *or*crystal diode. It is a two terminal unidirectional (allows current only in single direction) semiconductor device. The lead connected to p-side called **anode** and the lead connected to n-side called **cathode** of the diode. The circuit symbol of diode is shown in figure.



This pn junction does not allow flow of current. To make it suitable for electronics circuits we need to biasing (applying external voltage) pn-diode. There are two ways of biasing pn-diode (i) Forward biasing

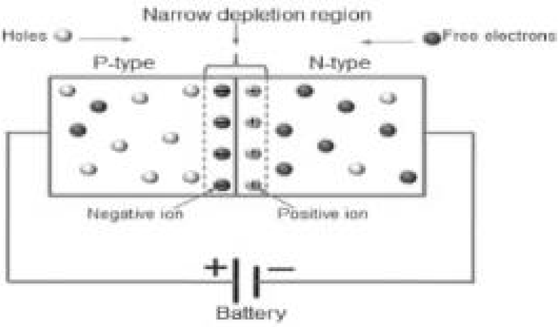
(ii) Reverse biasing

(i) Forward biasing

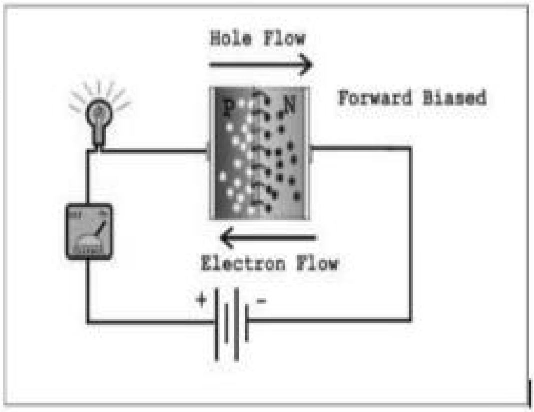
When a diode is connected in a **Forward Bias** condition, a negative voltage is applied to the N-type material and a positive voltage is applied to the P-type material.

Like charges repel, so the free electrons are pushed toward the PN junction. Similarly, the holes are repelled by the positive terminal of the battery toward the PN junction. If the voltage pushing the electrons and holes has sufficient strength to overcome the depletion zone (approximately 0.7 V for typical silicon diode) the electrons and holes combine at the junction and current passes through the diode.

The forward voltage at which the deplation region vanishes and the current in diode raises rapidly is called '**Knee voltage**'.



Forward bias

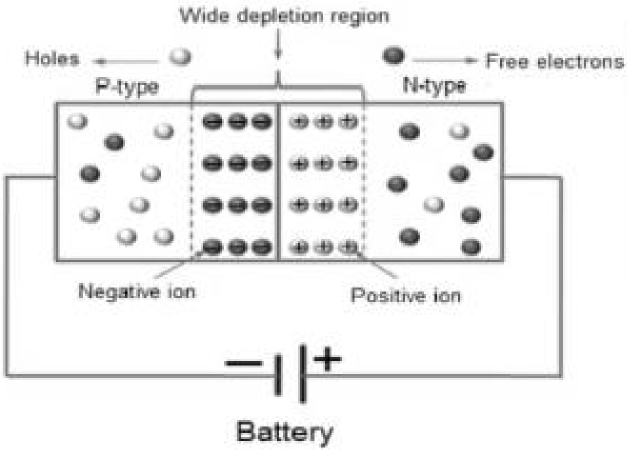


(ii)Reverse biasing

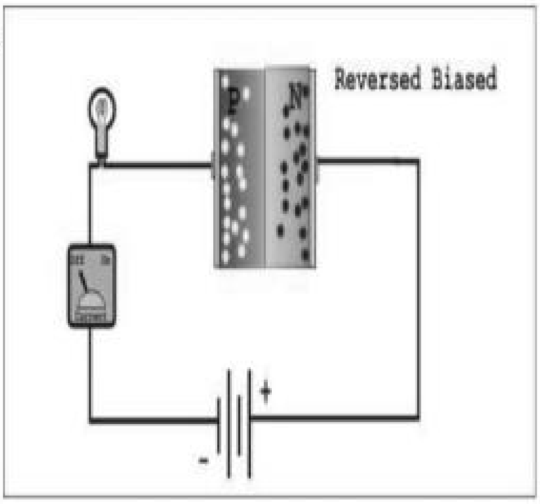
When a diode is connected in a **Reverse Bias** condition, a positive voltage is applied to the N-type material and a negative voltage is applied to the P-type material.

The negative terminal attracts the positive holes in the P-type silicon and the positive terminal of the battery attracts the free electrons in the N-type silicon. All the charge carriers are pulled away from the PN junction which essentially creates a larger depletion region. In reverse bias condition there is a small reverse leakage current because of minority carriers which is independent of reverse supply voltage called '**Reverse saturation current'**.

The minimum reverse voltage at which pn junction breaks down with sudden rise in reverse current is called **'Breakdown voltage'**.



Reverse bias



VI characteristics of pn-diode

Volt-ampere (V-I) characteristics of a pn-diode is the graphical representation of the curve between voltage across the junction and the current through the circuit.Normally the voltage is taken along the x-axis and current along y-axis.

Applications of Diode

In forward bias condition, the diode allows electric current whereas in reverse bias condition, the diode does not allow electric current. Due to this characteristic, the diode finds number of applications as given below:

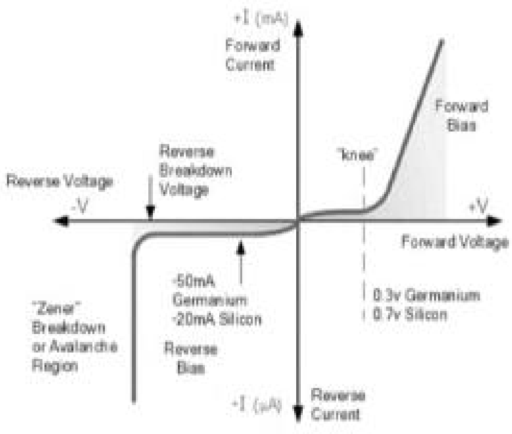
i. Rectificatioe
ii. Clipper & Clamping circuits
iii. Voltage regulating circuits
iv. Light emitting diodes(LED) & Laser diodes
v. Switching Circuits

Note:-

The breakdown occurs In reverse bias condition is two types as described below

i. Avalanche Breakdown

When the electric field is applied across the diode, the velocity of the charge carrier increases. This charge carrier collides with the other atoms and creates the pairs of hole and electrons. The free charge carrier further collides with other atoms and creates more pairs of electron and hole. These free electrons start moving across the junction and develop the reverse bias current. The reverse bias current completely destroys the junction. And once the junction breakdown occurs, it cannot regain its original position. It occurs in the lightly doped pn junction having thick depletion region.



ii. Zener Breakdown.

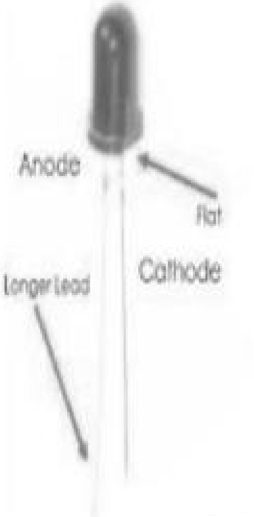
When the high electric field is applied across the junction, the charge carrier starts jumping across the junction. These electrons constitute the heavy current in the reversed direction. In Zener breakdown, the temporary breakdown of junction occurs. The junction regains its original position when the reverse voltage removes. It occurs in the heavily doped pn junction having thin deplation region.

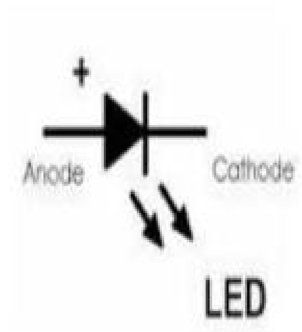
Difference between avalanche breakdown and zener breakdown

Avalanche Breakdown	Zener Breakdown
The process of applying high voltage and increasing the free electrons or electric current in semiconductors and insulating materials is called an avalanche breakdown.	The process in which the electrons move across the barrier from the valence band of p-type material to the conduction band of n-type material is known as Zener breakdown.
It occurs in diodes that are lightly doped.	It occurs in diodes that are highly doped.
The valence electrons are pushed to conduction due to the energy imparted by accelerated electrons, which gain their velocity due to their collision with other atoms.	The valence electrons are pulled into conduction due to the high electric field in the narrow depletion region.
The increase in temperature increases the breakdown voltage.	The increase in temperature decreases the breakdown voltage.
The VI characteristic curve of the avalanche breakdown is not as sharp as the Zener breakdown.	The VI characteristics of a Zener breakdown has a sharp curve.
This is observed in Zener diode having a Zener breakdown voltage Vz greater than 8 volts.	This is observed in Zener diodes having a Zener breakdown voltage Vz of 5 to 8 volts.

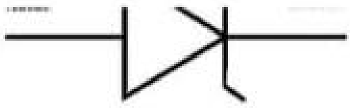
Zener Diode

Zener diode is an ordinary diode which is properly doped so that it has a sharp breakdown voltage. Unlike normal pn junction diode it allows current in forward bias as well as reverse bias condition. It starts conducting in reverse direction when reverse voltage reaches a predetermined value. Zener diode is mostly used in reverse bias condition only. The circuit symbol is shown in figure.





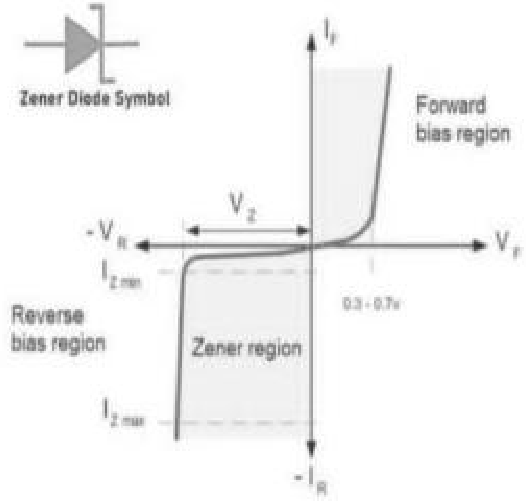
Working principle



When zener diode connected in the reverse mode, which is usual in most of its applications, a small leakage current may flow. As the reverse voltage increases to the predetermined breakdown voltage (Vz), a current starts flowing through the diode. The current increases to a maximum, which is determined by the series resistor, after which it stabilizes and remains constant over a wide range of applied voltage.

VI charecterstic of Zener diode

The graph between voltage and current of zener diode in forward bias is same as normal pn diode but in reverse bias it has sharp breakdown region at zener voltage Vz.



Applications

Zener diodes are mostly used in voltage regulator, overvoltage protection & clipper circuits.

Light Emitting diode (LED)

A **light-emitting diode (LED)** is a special purpose diode that gives off fairly narrow bandwidth of visible or invisible light when forward biased.The circuit symbol is shown in figure.

These are made by using elements like gallium, phosphorus and arsenic instead of normal Silicon and Germanium materials.

When light-emitting diode (LED) is forward biasedthe electrons from the *n*-type material cross the *pn*junction and recombine with holes in the *p*-type material. These free electrons are in the conduction band and at a higher energy level than the holes in the valence band. When recombination takes place, the recombining electrons release some part of energy in the form of heat and light. In Si &Ge diodes these energy dissipate in the form of heat but in Galium-Arsenide-phosphorous (GaAsP) and Galium-phosphorous (GaP) semiconductors, the electrons dissipate energy in the form of photons.

Light Emitting Diodes are made from exotic semiconductor compounds such as Gallium, Arsenide, Phosphorus all mixed together at different ratios to produce a distinct wavelength of colour given in the table.

Semi conductor	abbr,	Colour(s)
Aluminium-gallium-arsenide	AlGaAs	red
Aluminium-indium-gallium-phosphide	AlInGaP	red, yellow
Gallium-arsenide-phosphide	GaAsP	red, orange, yellow
Indium-gallium-nitride	InGaN	green, blue

Applications

LEDs are mostly used in power indicator, TVs and seven segment displays.

1.7 Integrated circuits (I.C) & its advantages.

An **integrated circuit** sometimes called **Chip** or **Microchip**is one in which thousand no of circuit components like transistors, diodes, resistors, capacitors etc. arefabricated on a small semiconductor chip.

It consist of a number of circuit components (*e.g.* transistors, diodes, resistors etc.) and their inter connections in a single small package to perform a complete electronic function and the individual components cannot be removed or replaced.

The size of this is so small that we need microscope to see the inter connections.

Advantages of IC

Integrated Circuits has many advantages over discrete circuits such as:

(i) Extremely small in size,

(ii) Low power consumption,

(iii) Reliability,

(iv) Reduced cost,

(v) Very small weight

(vi) Easy replacement.

Chapter Review Questions:

1. Define Electronics & its application.
2. Define work function.
3. Define Electronic Emission & different types of Emission.
4. Explain Conductor, Semiconductor & Insulator with respect to energy band diagram only.
5. Define doping.
6. Define energy gap & valence electrons.
7. Discuss Intrinsic Semiconductor.
8. Discuss Extrinsic Semiconductor.
9. Define accepter & donor atom.
10. List different types of Impurity.
11. Explain the difference between vacuum tube & semiconductor.
12. State basic concept of integrated circuits (I.C) & its use.
13. Explain P-type and N-type semiconductor junction.
14. Define PN junction Barrier voltage, depletion region, Junction Capacitance.
15. Draw Forward biased & reversed biased junction Diode.
16. Draw symbol, circuit diagram for characteristics (Forward & reversed) Characteristics PN junction diode.
17. Explain Construction (reference to doping level),Symbol ,circuit diagram for characteristics (forwarded & reversed) of Zener Diode.
18. Explain Avalanche &Zener breakdown and its comparison.
19. Explain Construction ,Symbol ,circuit diagram for characteristics of LED.