CHAPTER 2:

SEMICONDUCTOR DIODES

(MARKS = 24)

2.1 P.N. Junction Diodes

Working principle & circuit diagram of characteristic of PN junction diode, Static & dynamic resistance, specification, forward voltage drop, maximum forward current power dissipation.

2.2 Zener diode

Constructional diagram, symbol, circuit diagram and characteristics of Zener diode Specification: Zener voltage, power dissipation, dynamic resistance

2.3 Special Diodes

Construction, symbol & applications of PIN diode, Schottky diode, Tunnel diode

2.4 Optical diodes

Construction, symbol, operating principle & applications of LED, IRLED, Photodiode, Laser diode

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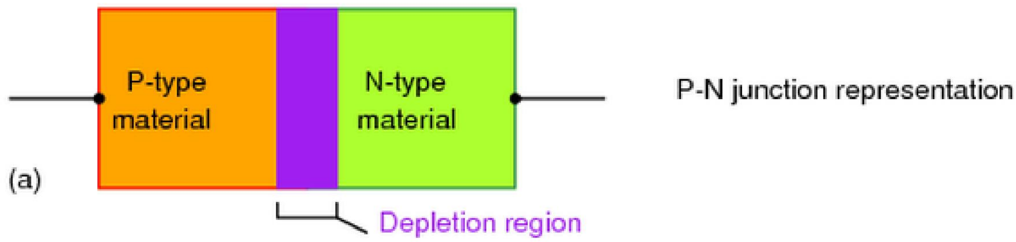
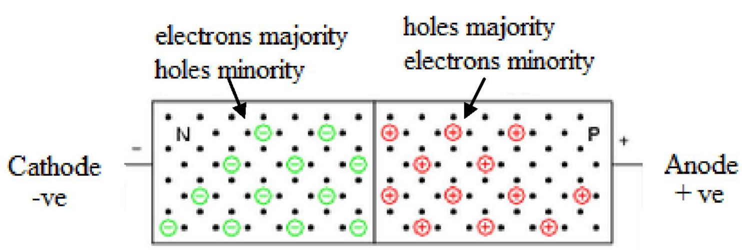
P-N Junction:

- As shown in the fig. a p-type semiconductor and n-type semiconductor are joined together with the help of a special fabrication technique to form a p-n junction.



- Terminals are brought out for the external connection with p and n type semiconductors. The p-side is called anode and the n-side is called the cathode.

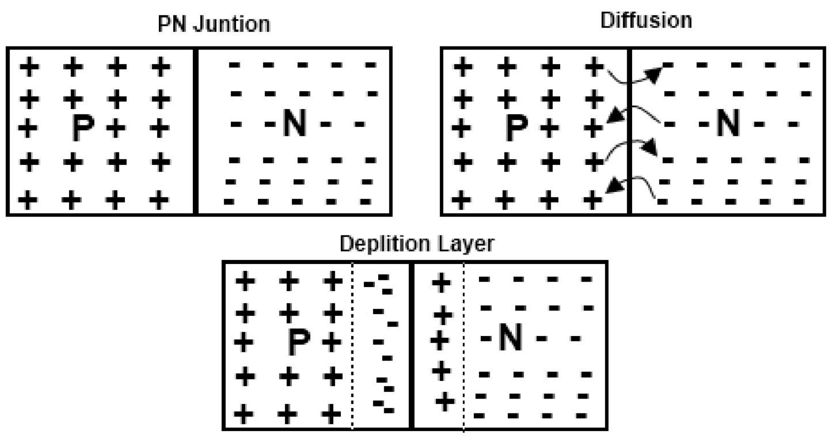


- The 'n' side consist of large no. of electrons and few thermally generated holes whereas, the 'p' side consist of large no. of holes and few thermally generated electrons.
- Thus the electrons are the majority carriers and the holes are the minority carriers in n-region and vice-versa in the p-region.
- The p-n junction forms the basic semiconductor device called the diode.

Formation of Depletion Region:

- When no external voltage is applied between the terminals of p-n junction, hence the pn junction is unbiased.
- The holes, from the p-region diffuse to the n-region, where they combine with the free electrons.

- The free electrons from ‘n’ side will diffuse into the ‘p’ side and recombine with the holes present there.

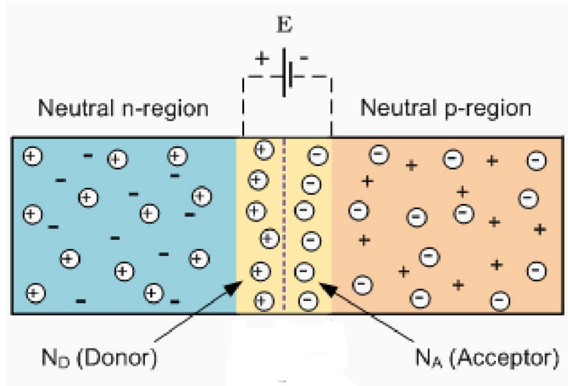


- When an electron combines with the hole on the p-side, an atom which accepts this electron loses its electrically neutral status and becomes a –ve immobile ion.
- Due to this recombination process, a large no. of +ve ions accumulate near the junction on the n-side and a large no. of –ve immobile ions will accumulate on the p-side near the junction as shown in the fig. above.
- The –ve charge ions on the p-side will start repelling the electrons which attempt to diffuse into the p-side and after sometime the diffusion will stop completely.

<u>Depletion region:</u>

- The area on both sides of junctions contains only immobile ions and no free charge carriers such as electrons or holes.
- In other words this region is ‘depleted’ of the free charge carriers.
- Therefore, this region is called ‘depletion region’.
- This region is also known as the ‘space charge region’. In the state of equilibrium, the depletion region gets widened to such an extent that electrons cannot cross the junction any more.

Barrier Potential or Junction Potential:



- Due to the presence of immobile positive and negative ions on opposite sides of the junction, an electric field is created across the junction.
- This electric field is known as the 'barrier potential' or 'junction potential' or cut-in voltage. It has fixed polarities.
- The polarities of barrier potential are decided by the type of immobile ions present on the two sides of the junction. Thus the –ve terminal of the barrier potential is on the p-side and +ve side is on the n-side.
- This is called as barrier potential because it acts as a barrier to oppose the flow of electrons and holes across the junction.
- The barrier potential represents the height of the barrier that is to overcome for commencement of flow of electrons and holes.
- Barrier potential is measured in volts. The barrier potential for **silicon is about 0.7 V** whereas the value for the **Germanium is 0.2 V** at 25.

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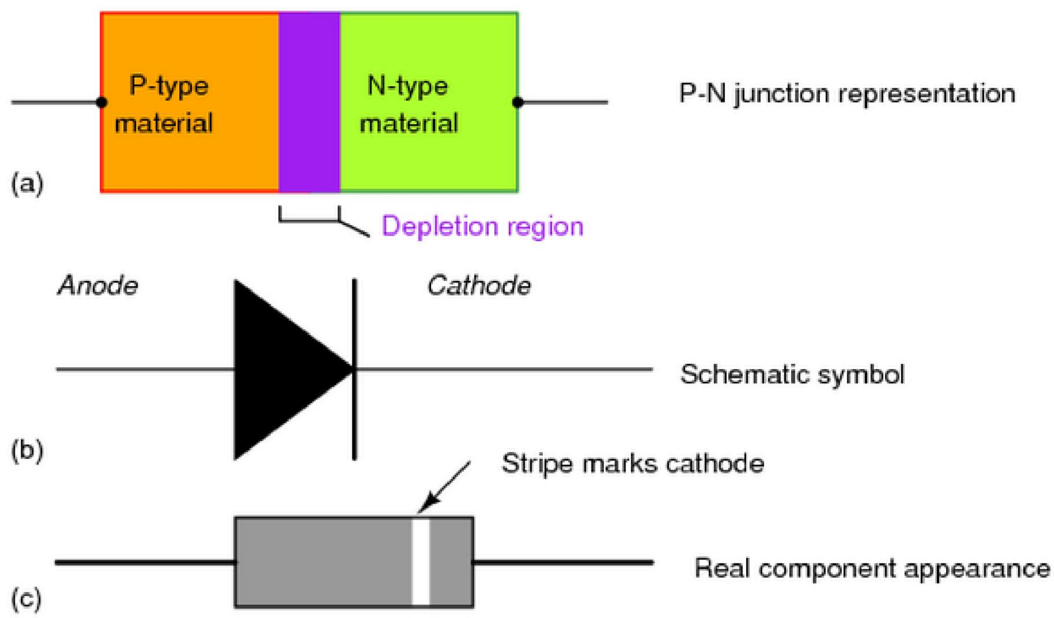
P-N Junction Diode:

- The p-n junction itself forms the most basic semiconductor device called Semiconductor diode. Thus semiconductor diode and the p-n junction are one and the same.
- The meaning of the term "diode" is the device having "two electrodes" (diode).



- Symbol and real component appearance is shown in the fig above.

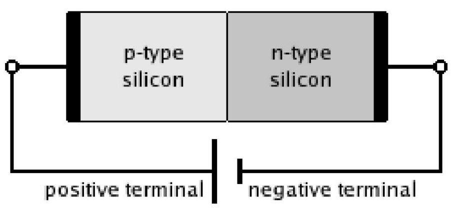
Biasing of P-N Junction diode:

- A P-N Junction, connected to an external voltage source is called a biased PN Junction.

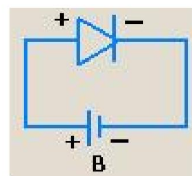
- By applying an external voltage across a PN junction, we are able to control the width of the depletion layer. This allows us to control the resistance of the PN junction and also the amount of current that can pass through the device.
- There are two ways of connecting voltage source to a PN junction as discussed below.
    1. Forward bias.
    2. Reverse bias.

Forward Bias of a PN junction diode:

- If the p-region (anode) is connected to the +ve terminal of the external DC source and n-side (cathode) is connected to the –ve terminal of the DC source then the biasing is said to be "forward biasing".



Forward biasing of diode

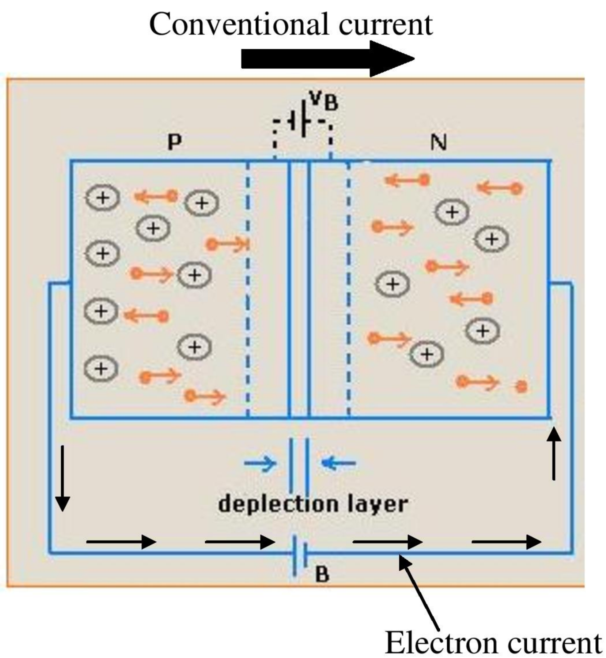


Symbolic representation

Operation of a forward biased diode:

- Due to the –ve terminal of external source connected to the n-region, free electrons from n-side are pushed towards the p-side. Similarly the +ve end of the supply will push holes from p-side towards the n-side.
- With increase in the external supply voltage V, more and more no. of holes (p-side) and electrons (n-side) start travelling towards the junction.
- The holes will start converting the –ve ions into neutral atoms and the electrons will convert the +ve ions into neutral atoms. As a result of this, the width of depletion region will reduce.
- Due to reduction in the depletion region width, the barrier potential will also reduce. Eventually at a particular value of the depletion region will collapse. Now there is absolute no opposition to the flow of electrons and holes.

- Hence a large no. of electrons and holes (majority carriers) can cross the junction under the influence of externally connected DC voltage.

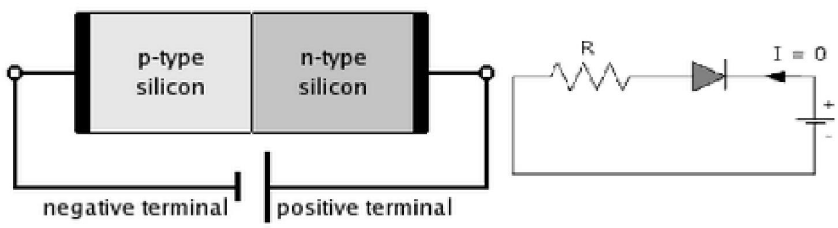


- The large no. of majority carriers crossing the junction constitutes a current called as the forward current.
- The current flown shown in the fig above is the electron current which is opposite direction to that of the conventional current.
- With increase in the forward bias, the width of the depletion region decreases and so does the barrier potential.

<u>Reverse Biased PN junction Diode:</u>

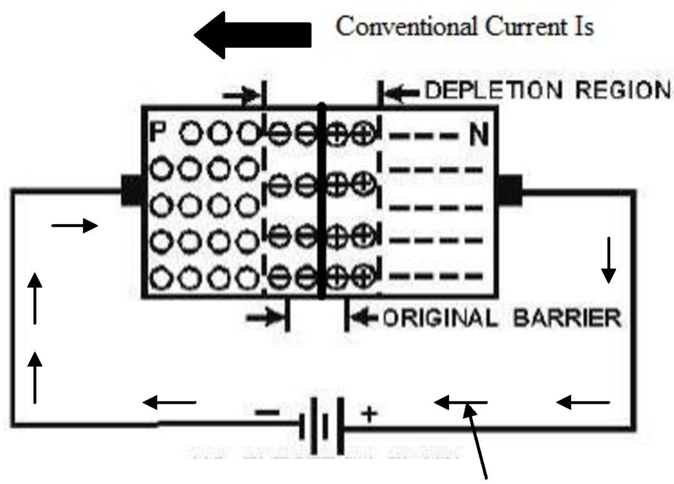
- If the p-region of a diode is connected to the –ve terminal of the external DC supply and n-region is connected to the +ve terminal of the DC supply, then a diode is said to be “reverse biased”.
- The fig below shows the reverse biasing schematically. The reverse current id denoted by Is and it flows from cathode to anode of the diode.

- Thus reverse current flows exactly in the opposite direction to that of the forward current.



Operation of a Reverse biased diode:

- When a diode is in reverse biased, holes in the p-region are attracted towards the –ve terminal of the supply and electrons on the n-side are attracted towards the +ve terminal of the supply as shown in fig. below.



- Due to the movement of electrons and holes away from the junction, width of the depletion region increases as shown in the fig above. This happens due to the creation of more no. of +ve and –ve immobile ions.
- Due to more no. of ions present on opposite sides of the junction, the barrier potential or junction potential will increase.
- The process of widening of depletion region does not continue for a long time, because there is no steady flow of holes from right to left i.e. from the n-side to p-side.

Reverse Breakdown :

- P-N junction allows a very small amount of current (called reverse saturation current), when it is reverse biased. This current is due to the movement of minority carriers across the junction and is independent of the applied reverse voltage.
- If the reverse bias is increased to a large value, the current through the junction increase abruptly.
- The voltage, at which this action (i.e. abrupt increase) occurs, is known as breakdown voltage.
- The following two processes cause junction breakdown due to increase in reverse voltage.

1. Zener Breakdown:
   - In this case the breakdown occurs in junctions, which are heavily doped. The heavily doped junctions have a narrow depletion layer.
   - When the reverse voltage is increased, the electric field at the junction also increases.
   - A strong electric field causes a covalent bond to break from the crystal structure.
   - As a result of this, a large no. of minority carriers are generated and a large current flows through the junction.

2. Avalanche Breakdown:

- In this case, the increased reverse voltage increases the amount of energy imparted to minority carriers, as they diffuse across the junction.
- As the reverse voltage is increased, further, the minority carriers acquire a large amount of energy (or momentum).
- When these carriers collide with silicon (or germanium) atoms, within the crystal structure, they impart sufficient energy to break a covalent bond and generate additional carriers (i.e. electron-hole pairs).

- These additional carriers pick up energy from the applied voltage and generate still more carriers.
- As a result of this, the reverse current increases rapidly.
- This cumulative process of carrier generation (or multiplication) is known as Avalanche breakdown or Avalanche multiplication.

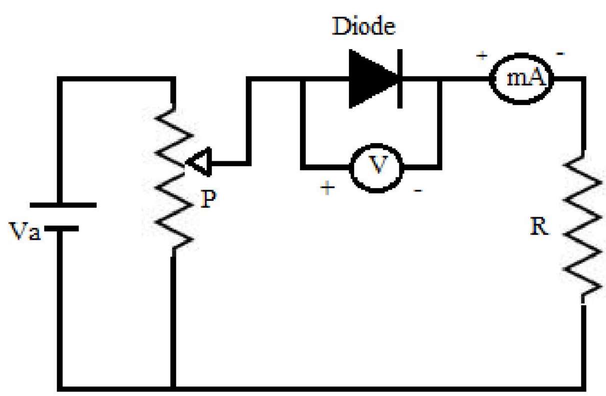
V-I characteristics of a Diode:

The V-I characteristics can be divided in two parts.

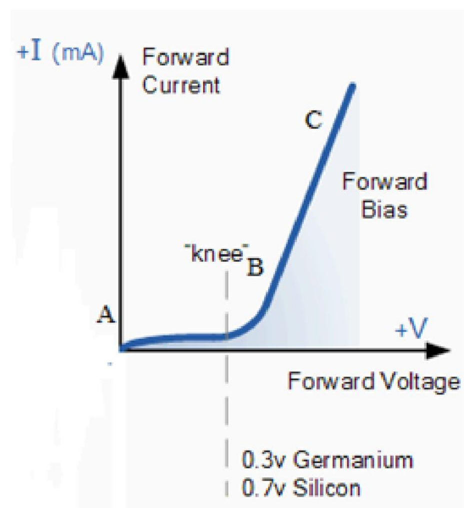
1. Forward characteristics.
2. Reverse characteristics

Forward characteristics of P-N Junction Diode.

- The forward characteristic is the graph of the anode to cathode forward voltage 'Vf' verses the forward current through the diode 'If'.
- The forward characteristics are divided into two portions AB and BC as shown in the fig below.



Circuit arrangement



Forward characteristics

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Region A to B:

- In this region A to B of the forward characteristics shown in the fig, the forward voltage is small and less than the cut in voltage.
- Therefore the forward current flowing through the diode is small.
- With further increase in the forward voltage, it reaches the level of the cut in voltage and the width of depletion region grows on decreasing.

Region B to C:

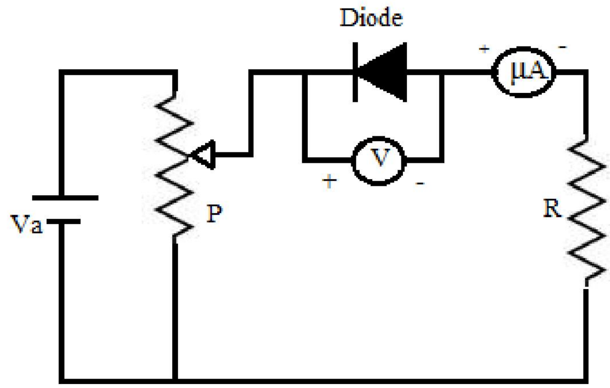
- As soon as the forward voltage equals the cut in voltage, current through the diode increases suddenly. The nature of this current is exponential.
- The large forward current in the region B-C of the forward characteristics is limited by connecting a resistor 'R' in series with the diode. Forward current is of the order of a few mA.
- The forward current is a conventional current that flows from anode to cathode.
- Therefore it is considered to be positive current, and the forward characteristics appears in the first quadrant as shown in the fig.

Cut in voltage (Knee Voltage):

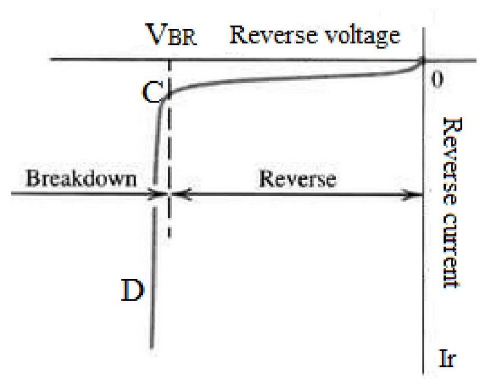
- The voltage at which the forward diode current starts increasing rapidly is known as the cut-in voltage of a diode. As shown in fig above, the cut in voltage is very close to the barrier potential. Cut-in voltage is denoted byV_T. Cut-in voltage is also called as Knee voltage.
- Generally a diode is forward biased above the cut-in voltage. The cut-in voltage for a silicon diode is 0.6V and that for germanium diode is 0.3V.

Reverse Characteristics of Diode:

- The minority electrons in the p-region are attracted by the positive end of the dc supply. Hence these electrons will cross the junction and constitutes reverse current ‘Ir’ of the diode as shown in the fig.



Circuit arrangement (fig a)



Reverse characteristics (fig b)

- Since reverse current is very much less the resistance offered by reverse biased diode is very high of the order of few ‘KΩ’.

Reverse Characteristics:

- The circuit arrangement for obtaining the reverse characteristics of the diode is shown in the fig above.
- The milli-ammeter is replaced by micro-ammeter.
- The applied reverse voltage is gradually increased above zero in suitable steps and the values of diode current are recorded at each step.
- Because of the minority carrier there will be small amount of current flowing through the diode is called reverse saturation current.
- Now, if we plot a graph with reverse voltage on horizontal axis and current on vertical axis, we obtain a curve marked OCD as shown in the fig.
- The curve OCD is called reverse characteristics of diode.

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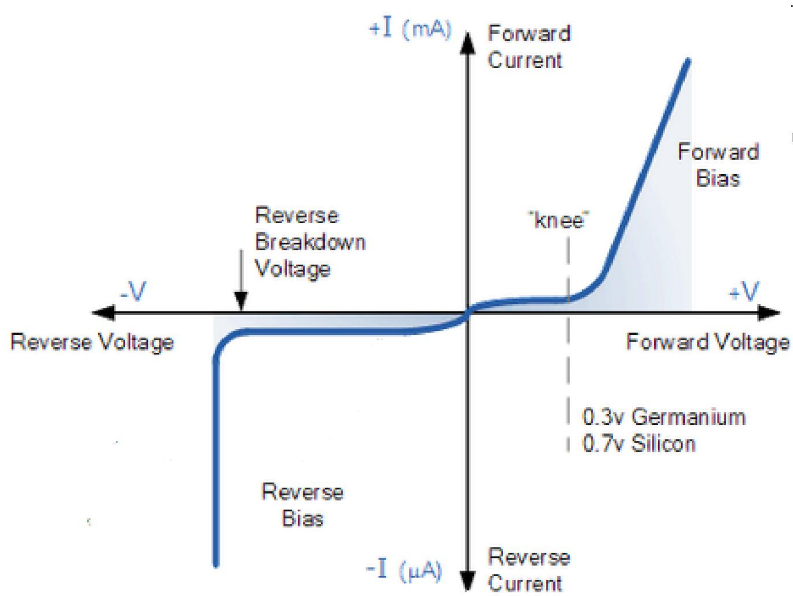
Breakdown Voltage:

When the reverse voltage is increased sufficiently large value, the diode reverse characteristics current increases as rapidly as shown by curve CD. The applied reverse voltage at which this happens is known as breakdown voltage (V_{BR}) of a diode.

Combined V-I Characteristics of a P-N junction:



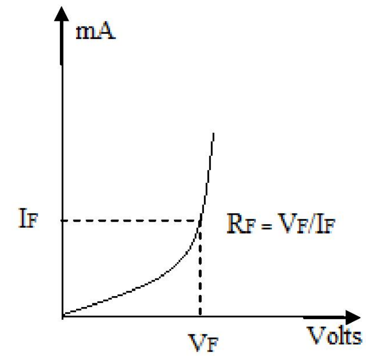
DC or Static Resistance:

- When a DC voltage is applied to a diode, a DC current will flow through it and the operating point on the characteristics curve of the diode will not change its position with time.

Definition:

- The resistance of the diode at the operating point can be obtained by taking the ratio of V_F and I_F. This resistance offered by the diode to the forward DC operating conditions is called as 'DC or static resistance' and it is denoted by R_F. This is shown in fig below.

Static Resistance $R_F = V_F / I_F$.



- Similarly we can define the static resistance of a diode in the reverse bias condition as R_R. It is the ratio of reverse voltage to reverse current at a particular operating point.
- The typical value of forward static resistances R_F is between 10Ω to 50Ω and that of R_R is a few hundred KΩ.

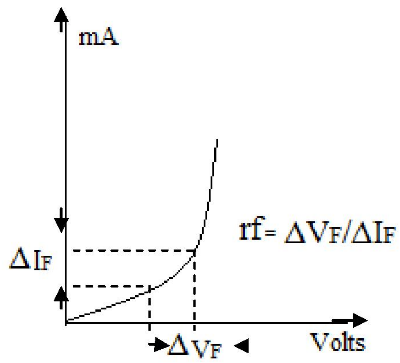
AC or Dynamic resistance (rd):

- When an AC voltage rather than a DC voltage is applied to a diode the situation is altogether different.
- The operating point of the diode does not remain fixed. Its position will keep changing continuously, due to change in the input voltage as shown in the fig below.

Definition:

- The resistance offered by the diode to the AC operating conditions is known as the 'Dynamic resistance' or 'Incremental resistance' or 'AC resistance' of a diode.
- It is denoted by r_f in the forward biased condition and r_r in the reverse biased condition.
- Dynamic forward resistance is defined as,

  $r_f = \Delta V_F / \Delta I_F$.



- Dynamic resistance is actually the reciprocal of the slope of the forward characteristics.

Diode Specifications:

1. Forward voltage Drop:

There is a potential drop across the conducting forward biased diode, which has opposite polarities to the barrier potential but has a magnitude which is approximately equal to barrier potential.

Vf = 0.7 V (for silicon diode)

Vf = 0.3 V (for Germanium diode)

2. Reverse Saturation current (Io) :

When the diode is reversed biased there is small amount of current flows through the diode because of minority carriers this current is called as reverse saturation current (Io) .

Io = Nano-amperes (for silicon diode)

Io = micro- amperes (for Germanium diode)

3. Maximum forward Voltage:

It is the highest instantaneous forward current that a p-n junction can conduct without damage to the junction.

4. Power dissipation or Maximum power rating:

It is the maximum power that can be dissipated at the junction without damaging it.

5. Peak Inverse Voltage:

It is the maximum reverse voltage that can be applied to the p-n junction without damage ti the junction. If the reverse voltage across the junction exceeds it's PIV the junction may be destroyed due to excessive heat.

6. Static Resistance:

It is given by the ratio of the DC voltage across the diode to the DC current flowing through it.

$R_F = V_F / I_F$.

7. Dynamic Resistance:

The AC resistance at a particular DC voltage is equal to reciprocal of the slope of the characteristics at the point.

$r_f = \Delta V_F / \Delta I_F$.

Zener Diode:

- A properly doped crystal diode which has a sharp breakdown voltage is known as Zener diode.
- The breakdown or Zener voltage depends upon the amount of doping.
- If the diode is heavily doped, depletion layer will be thin and consequently the breakdown of junction will occur at lower reverse voltage.
- On the other hand, a lightly doped diode has a higher breakdown voltage.

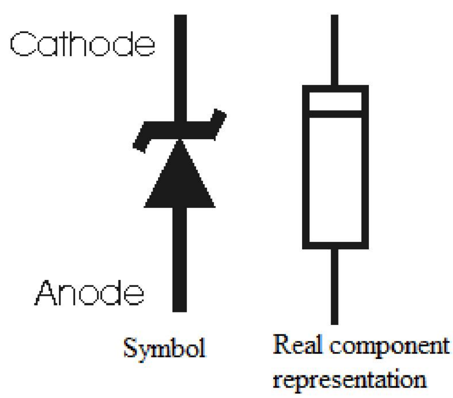
Construction:

- The zener diode are silicon P-N Junction devices which differ from normal P-N junction diodes, in the sense, they are operated in reverse breakdown region and the breakdown voltage is set by carefully controlling the doping level.

Operating Principle:

- The zener diode can be forward biased or reverse biased.
- Its operation in forward biased is same as that of P-N junction diode.
- Normally Zener diode is operated in reverse biased mode.

Symbol:



A zener diode has a sharp breakdown voltage called zener voltage Vz.

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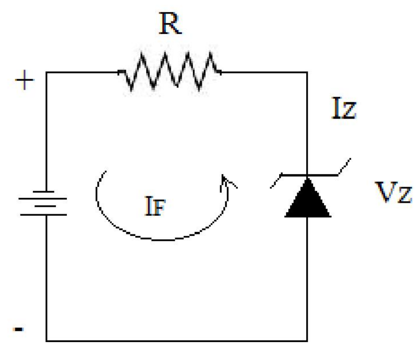
Forward Biasing of Zener Diode:



- When the anode of zener diode is connected to the +ve terminal of the DC source and the cathode is connected to –ve terminal the zener diode is said to be forward bias.
- The circuit diagram is for forward biasing is shown in fig. above
- When forward voltage greater than the potential barrier is applied, electron and holes will cross the junction and will constitute forward current (I_F) through the diode as shown in fog above.

Forward characteristics of Zener diode:

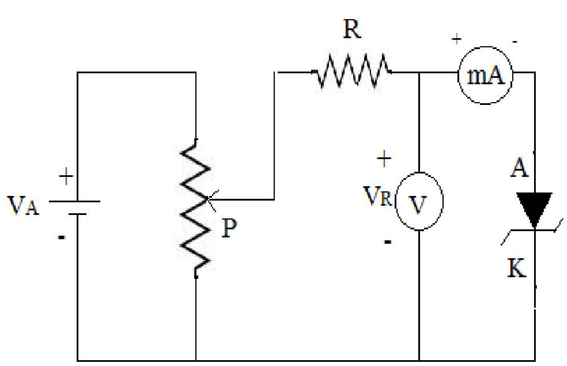


Fig (a)

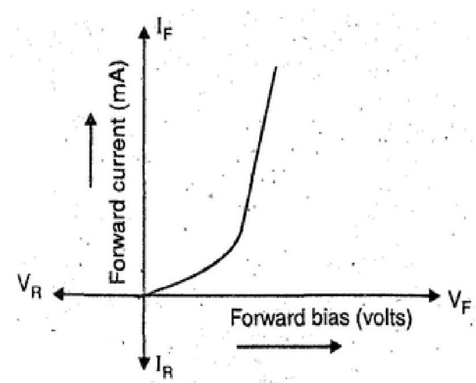


Fig (b)

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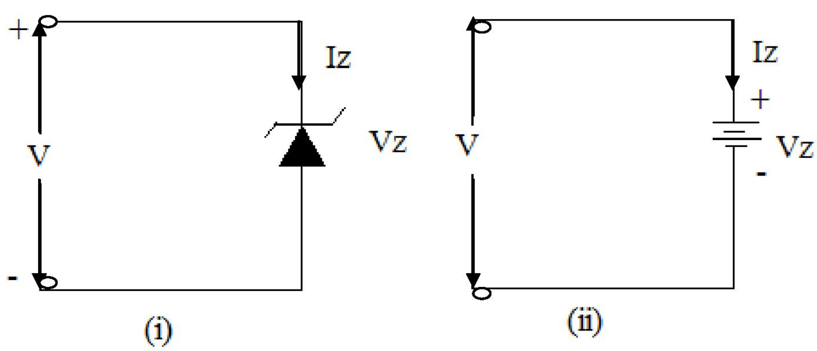
- The figure above shows experimental setup for plotting forward zener diode characteristics.
- This characteristic is similar to that of an ordinary silicon P-N junction diode.
- This indicates forward current is very small for voltages below knee voltage ($V_K = 0.7V$) and large for voltages above knee voltage.

Reverse Biasing of Zener diode:

- When the cathode of the diode is connected to the +ve terminal of DC source and anode is connected to –ve terminal Zener diode is said to be in reverse biased condition.
- The operation of reverse biased Zener diode can be explained in two modes.

1. "ON" State ($V >= V_Z$)
2. "OFF" State ($V_Z > V > 0$)

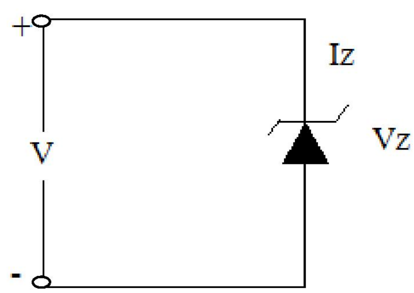
1. <u>"ON" State: ($V >= V_Z$)</u>



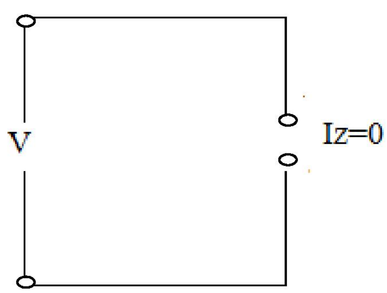
- When the reverse voltage across a Zener diode is equal to or more than breakdown voltage V_Z the current increases sharply.
- In this region, voltage across zener diode is constant at V_Z even though the current through it changes.
- Therefore in this region an ideal zener diode can be represented by battery of voltage V_Z as shown in fig.

- Under such conditions the zener diode is said to be in "ON" state.

2. <u>"OFF" State ($V_Z > V > 0$).</u>



(i)



(ii)

- When the reverse voltage across the Zener diode is less than V_Z but greater than 0V, the zener diode is in the "OFF" state.
- Under such conditions, the zener diode can be represented by an open-circuit as shown in fig (ii) above.

<u>Reverse characteristics of Zener diode:</u>

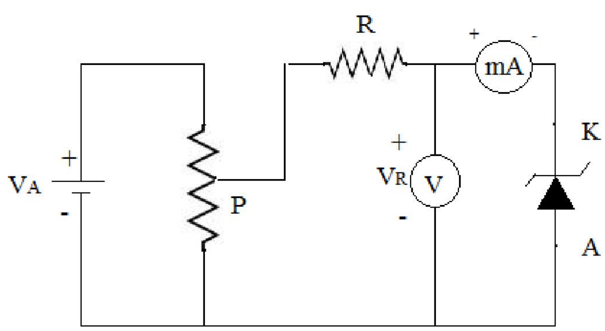


Fig (a)

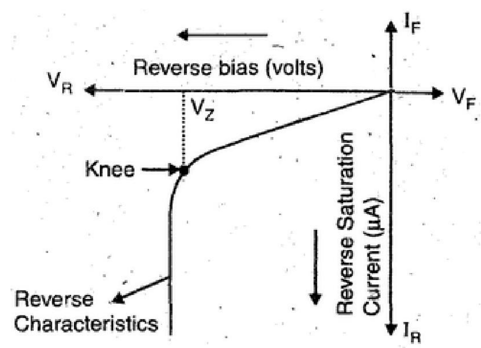


Fig (b)

- Fig above shows the reverse portion of V-I characteristics of the zener diode.
- As the reverse voltage (V_R) is increased the reverse current (I_Z) remains negligibly small up to the 'Knee' of the curve/
- At this point the effect of breakdown process begins.

- From the bottom of the knee, the breakdown voltage or zener voltage (V_Z) remains essentially constant.
- This ability of a diode is called regulating ability and is an important feature of Zener diode.
- Following two points are important from the characteristics of a zener diode.
- There is a minimum value of zener current called "breakover current" designated as I_{ZK} or I_Z(min) which much be maintained in order to keep the diode in regulation region.
- There is a maximum value of zener current designated as I_{ZM} or I_Z(max) above which the diode may be damaged.

<u>Specification of Zener diode</u>:

1. <u>Zener Voltage:</u>

It is the voltage at which Zener diode starts conducting in reverse biased mode and operated in Zener region. Beyond this voltage current through the diode remains constant.

2. <u>Power Dissipation:</u>

The power dissipation of zener diode is the product of breakdown voltage (V_Z) and the current (I_Z).

Mathematically the power dissipation

$$\boxed{P_Z = V_Z \times I_Z}$$

3. <u>Breakover current or Knee current (I_{ZK}) or minimum zener current Iz (min)</u>

Breakover current is the current flowing through the zener diode at the point of reverse breakdown.

4. Maximum Reverse current:

It is defined as the maximum reverse current that can flow through a zener diode without damaging it due to excessive heating.

5. Dynamic Resistance:

It is the ratio of change in Zener voltage (Vz) to change in zener current (Iz). It is also called as zener resistance or AC resistance.

Applications of Zener Diode:

- As a voltage regulator.
- As a fixed reference voltage in transistor biasing circuits.
- In peak clippers or limiters in waveshaping circuits.
- For meter protection against damage from accidental applications.
- In the protection circuits of MOSFET.

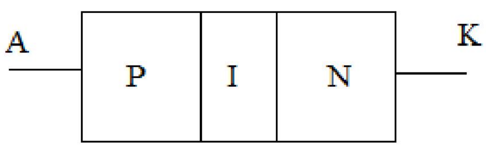
Special Diodes:

The following are the special type of diodes.

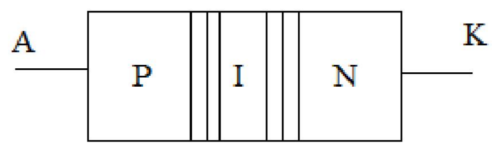
1. PIN Diode. 2. Schottky diode 3. Tunnel diode.

PIN Diode:

- A PIN diode is made up of three semiconductor materials: two heavily doped P-type and one N-type material separated by an intrinsic (i.e. undoped) semiconductor (I) as shown in the fig below.
- The intrinsic offers high resistance to the current flowing through it.



(a) Base Structure



(b) Formation of depletion layer

- The PIN diode has following two advantages over the normal diode.

1. The capacitance between the P and N region decreases because of the increased separation between the P and N regions. This advantage allows the PIN diode to have a fast response time.
2. There is a greater electron-hole pair generation because of the increased electric field between the P and N regions. This advantage allows the PIN diode to process even weak signals.

Construction:

- When the PIN diode is unbiased (i.e. no voltage is applied across the diode), there is diffusion of electron and holes across the junction due to the different concentration of atoms in the P, I and N regions.
- The diffusion of electrons and holes produce a depletion layer across the PI and IN junction as shown in fig above.

- The depletion layers penetrate to a little distance in the P-type and N-type semiconductor regions but to a larger distance in the I-region. Under such conditions, the device has a high value of resistance.
- When the PIN diode is forward biased, the width of depletion layers decreases. As a result of this, more carriers are injected into the I-region.
- This reduces the resistance of the I-region.
- Thus, when the PIN diode is forward biased, it acts like a variable resistance as shown in fig (a) below.
- On the other hand, when the PIN diode is reverse biased, the depletion layers become thicker. As the result reverse bias is increased, the thickness of the depletion layer increases till the I-region becomes free of mobile carriers.
- The reverse bias, at which this happens, is called swept out voltage.
- At this stage, the PIN diode acts like an almost constant capacitance as shown in fig (b) below.

<u>Symbol:</u>

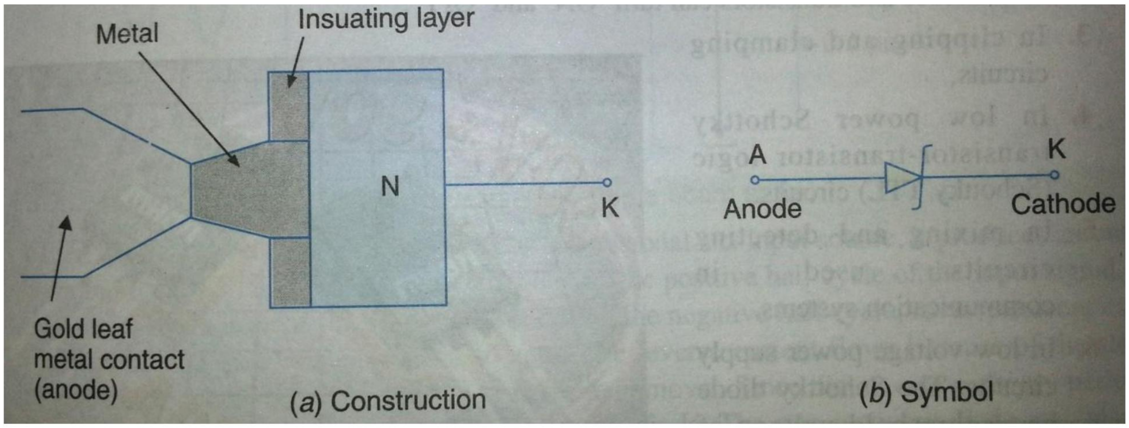
(a) Forward Biased (b) Reverse Biased

<u>PIN diode applications:</u>

- As a DC controlled microwave switch for switching high voltage/current at microwave frequencies.
- As an amplitude modulator at microwave frequencies beyond 1GHz.
- In attenuator applications because its resistance can be controlled by the current.

Schottky Diode:

Construction:



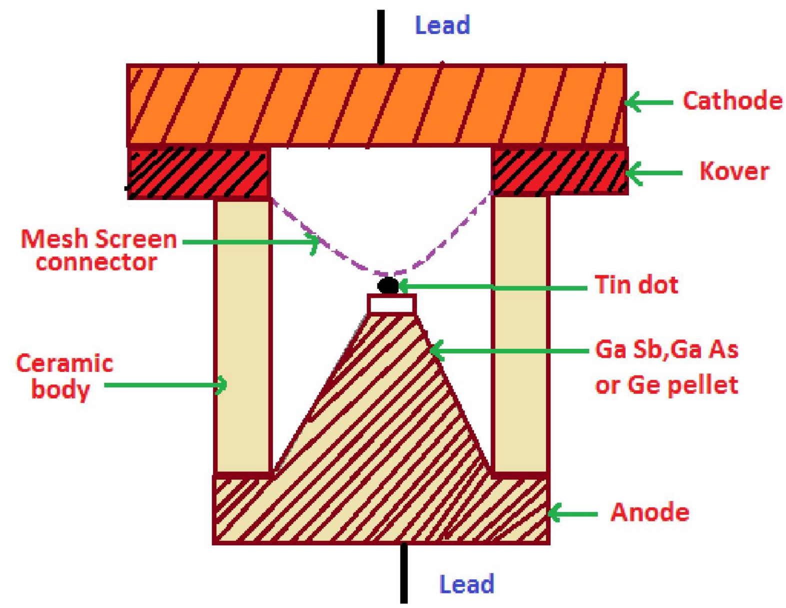
- It is formed by joining a doped semiconductor region (usually N-type) with a metal such as gold, silver or platinum.
- Thus in a schottky diode, there is a metal-to-semiconductor junction rather than a simple P-N junction as shown in fig above.
- A schottky diode is also called a hot carrier diode or a schottky barrier diode
- Fig (b) shows the schematic symbol of schottky diode. The line at the end of the arrow looks like the letter 'S'.

Applications:

- To rectify very high frequency (above 300) signals.
- As a switching device in digital computer.
- In clipping and clamping circuits.
- Mixers and detectors in communications equipments.

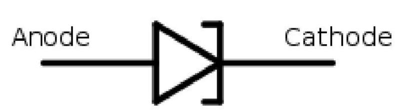
Tunnel Diode:

Construction:



- Tunnel diodes are usually fabricated from germanium, gallium or gallium arsenide.
- These all have small forbidden energy gaps and high ion motilities. Silicon is not used in the fabrication of tunnel diodes due to low (Ip,I v)value.
- A small tin dot is soldered or alloyed to a heavily doped pellet of n-type Ge, GaSb or GaAs.
- The pellet is then soldered to anode which is also used for heat dissipation.
- The cathode contact is connected to the tin dot via a mesh screen used to reduce inductance.
- The diode has a ceramic body and a hermetically sealing lid on top.

Symbol:



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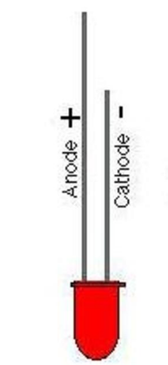
Applications:

- One of the important application of a tunnel diode is in high speed computers where the switching times in the order of nanoseconds or picoseconds are desirable.
- A tunnel diode can be used at such high speeds as a result of the electrons "punching through" at velocities that far exceed those in conventional diodes.
- The punching through takes place due to narrow depletion region.
- Some other applications are :
    1. In digital networks.
    2. As a high speed switch.
    3. As a high frequency oscillator.

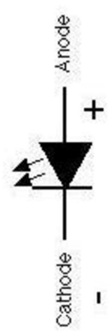
Optical Diodes:

1. Light Emitting Diodes (LED):

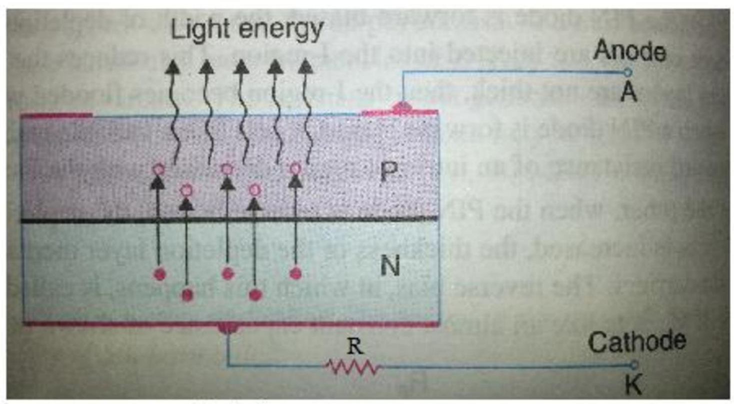
- A PN junction diode which emits light when forward biased is known as light emitting diode (LED).
- The amount of light output is directly proportional to the forward current.
- Thus higher the forward current, higher the output.
- The schematic symbol of LED is shown in the fig below. The arrows pointing away from the diode symbol represents the light, which is being transmitted away from the junction.



Real component representation

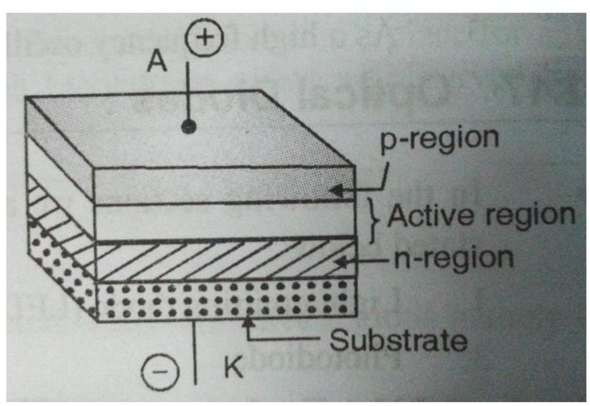


Symbol



Basic Structure

Construction of LED:

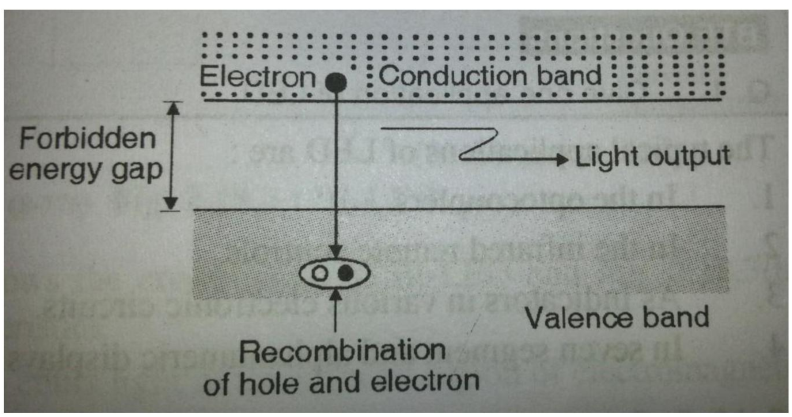


- Fig above shows the construction of LED.
- Here an N-type layer is grown on a substrate by a diffusion process.
- Then a thin P-type layer is grown on the N-type layer.
- The metal connections to both the layers make anode and cathode terminals as indicated.
- The active region exists between the P and N regions.
- The light energy is released at the junction when the electron hole pair recombination takes place.
- After passing through the P-region the light is emitted from the window provided at top.

Semiconductor Materials Used:

- Gallium Arsenide (GaAs) : Infrared (IR)
- Gallium Arsenide Phosphite (GaAsP) : Red or Yellow.
- Gallium Phosphite (GaP) : Red or Green.

Principle of Operation of LED:

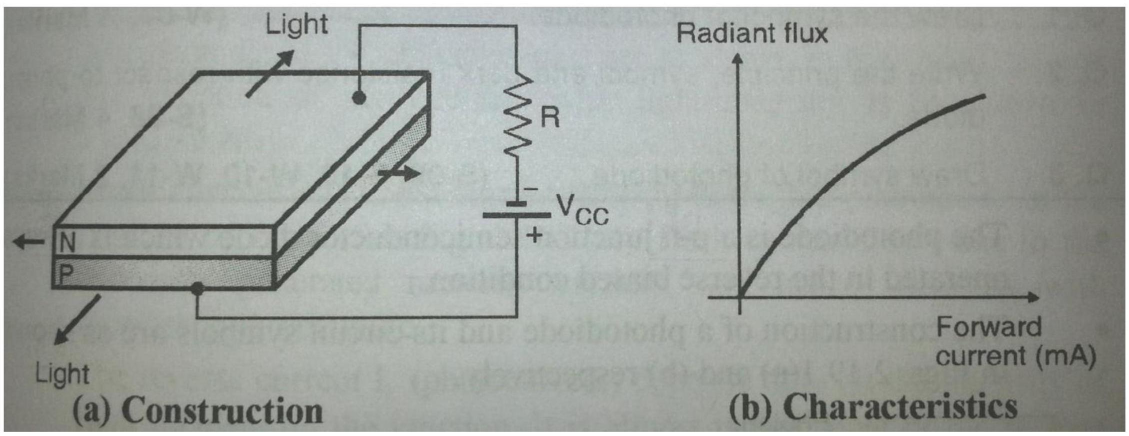


- When an LED is forward biased, the electron in the n-region will cross the junction and recombine with the holes is p-type.
- When the recombination takes place, electrons from the conduction band resides these electrons return back to the valance band.
- While returning back, the recombining electrons give away the excess energy in the form of light.

Applications of LED:

- As a power indicator.
- In seven segment display.
- In the opto-couplers.
- In the infrared remote controls.

2. Infra Red Light Emitting Diode (IR-LED):



- Fig (a) shows the construction of IR-LED and fig (b) shows its characteristics.
- This type of LED emits light in the infrared region of electromagnetic spectrum.

Operation:

- The IR-LED is a PN junction diode. It is of Gallium Arsenide (GaAs) and is operated in the forward biased condition.
- When the forward voltage is applied, the electrons from the n-side will recombine with the holes on p-side in the recombination region between p and n regions.
- During every recombination some of energy is released which is radiated in the form of Infra-Red light.

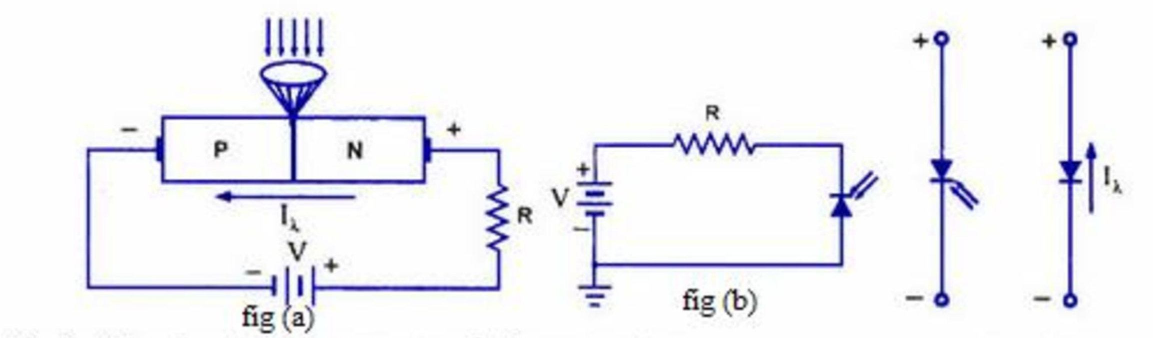
Applications of IR-LED:

- In remote control handsets.
- In optocouplers.
- In the shaft encoders.
- As a light source in optical fiber system.
- In the burglar alarm system.

3. **Photodiode:**

- A photo-diode is a reverse biased silicon or germanium PN junction in which reverse current increases when the junction is exposed to light.
- The reverse current in a photo-diode is directly proportional to the intensity of light falling on its PN junction.

Construction:



Basic Biasing Arrangement and Construction

Photodiode

Symbols

fig (c)

Principle:

- When a rectifier diode is reverse biased, it has a very small reverse leakage current .
- The reverse current is produced by thermally generated electron-hole pairs which are swept across the junction by the electric field created by the reverse voltage.

- In rectifier diode, the reverse current increases with temperature due to an increase in the number of electron-hole pairs.
- A photodiode differs from a rectifier diode in that when its PN junction is exposed to light, the reverse current increases with the increase in light intensity and vice versa.
- When light (Photon) falls on the PN junction energy is imparted by the photons to the atoms in the junction.
- This will create more free electrons (and more holes).
- These additional free electrons will increase the reverse current. As the intensity of light incident on the PN junction increases the reverse current also increases.

<u>Photo-Diode Operation:</u>

- Fig (b) shows the basic photodiode circuit. The circuit has reverse biased Photo-diode resistor 'R' and DC supply.

1. When no light is incident on the PN junction of Photo-Diode, the reverse current Ir is extremely small. This is called Dark Current.

<u>Dark Resistance:</u>

The resistance of photodiode with no incident light is called Dark Resistance.

2. When light is incident on the PN junction of the PhotoDiode, there is a transfer of energy from the incident light (photon) to the atoms in the junction.
   This will create more free electrons (and more holes). These additional free electrons will increase the reverse current.
3. As the intensity if light increases the reverse current Ir goes on increasing till it becomes maximum. This is called saturation current.

<u>Applications:</u>

- Object counting system.
- Alarm circuits.
- In fiber optic receiver.

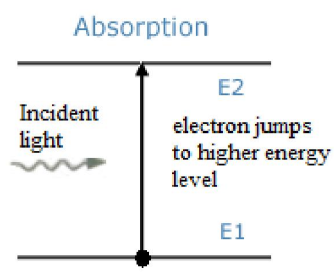
- In the cameras for sensing the light internsity.

LASER Diode:

The word LASER is the acronym for Light Amplification by Stimulated Emission of Radiation.

The three basic steps in generation of a LASER are:

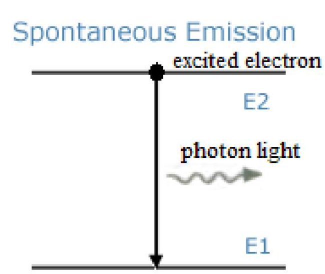
1. Absorption:



When light is incident on photo sensitive material, electron absorbs the energy from incident photon and move to a higher energy level as shown in the fig. above

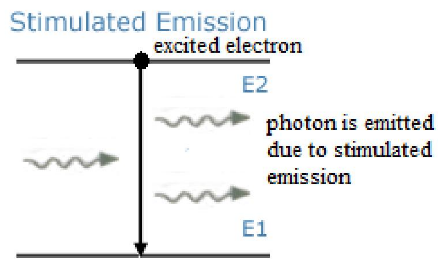
2. Spontaneous Emission:

- After absorption electrons are present on higher energy level and this is called excited electron.
- If no light is incident on them then they cannot stay for longer time at higher energy level.
- After short excited electrons will fall back to their original energy level and emits the energy in the form of photon (light).
- This process is called Spontaneous emission.



3. Stimulated Emission:

- In this process "amplification" of light takes place.
- If light energy strikes to the excited electron present in higher energy level, then electron will fall back to its original level.
- While returning back it will emit two photons. So one incident photon causes emission of two photons and hence light amplification takes place.
- This principle is used in LASER diode.



Construction:

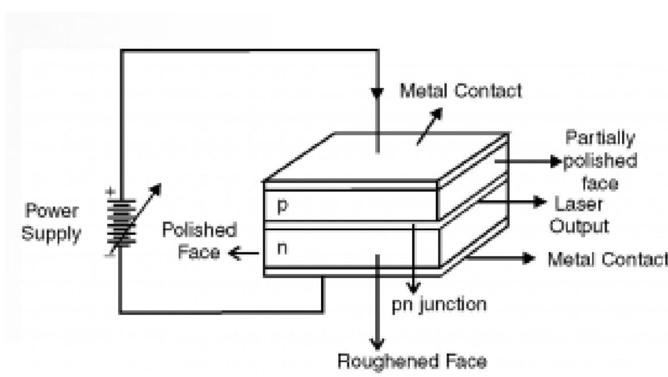
Broadly speaking the laser diode structure can be divided into two categories.

1. Surface-emitting laser diode:

These laser diodes wmit light in a direction perpendicular to the PN junction.

2. Edge-emitting laser diode:

These laser diodes emit light in a direction parallel to the PN junction plane.



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- Fig above shows the structure of an edge-emitting laser diode.
- As seen in the fig a PN junction is formed by two layers of doped Gallium Arsenide (GaAs).
- As seen, there is a highly reflective surface at one end of the junction and partially reflective surface at the other end.
- External leads provide the anode and cathode connection.

Operation:

- When the PN junction is forward biased by an external voltage source, electrons move across the junction and usual recombination a\occurs in the depletion region which results in the production of photons.
- As forward current is increased, more photons are produced which drift at random in depletion region.
- Some of these photons strike the reflective surface perpendicularly. These reflected photons move back and forth between two reflective surfaces as shown in fig above.
- The photon activity becomes so intense that at some point a strong beam of laser comes out of the partially reflective surface of the diode.

Applications:

- As a light source in fiber optic communication.
- Medical equipments used in surgery.
- Optical disk equipment.
- Laser printers.
- Hologram scanners.