Chapter - 4

SEMICONDUCTOR, DIODE

→ formation of P-N junction, depletion region barrier potential

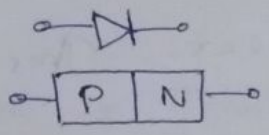
→ Biasing of P-N junction, forward bias, Reverse bias.

→ V-I characteristics of Diode, static & Dynamic Resistance

→ Zener diode, Breakdown mechanisms Zener Breakdown & Avalanche Breakdown

→ V-I chara of Zener diode

P-N Junction



When a P-type semi-conductor is suitably joinbed to an N-type semi-conductor, a PN junction is formed. Such a PN junction is the basic building block of all the semi-conductor devices.

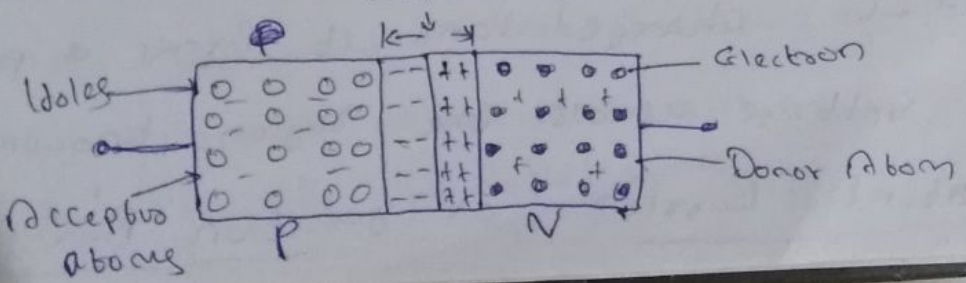


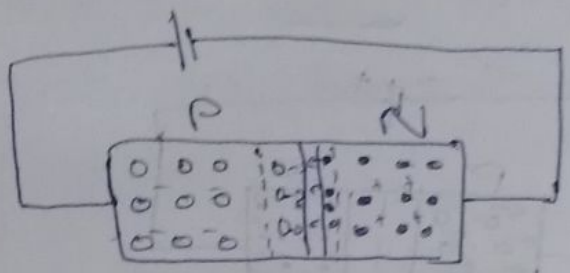
Fig shows an immediately formed P.N junction. Here the e^-s in N-type material diffuse into P-type & holes in P-type material diffuse into N-Type material Particularly ~~close~~ close to the region e^- coming to P-region gets -ve charged ions and holes coming N-region gets +ve charged ions.

After a few recombinations of holes and electrons, a narrow width of fixed +ve charges on N-side and fixed -ve charge on P-side of the junction will appear. This region is known as Depletion region. also known as Space charge region.

on the combinations of these +ve and -ve charged ions it forms a potential or voltage across the region known as Potential Barrier or junction Barrier

for Silicon(Si) PN junction potential barrier is about 0.7 volt. for Germanium it is 0.3V.

PN Junction with forward biasing



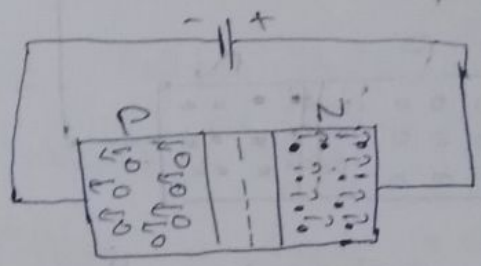
When an external voltage applied across a PN junction is such a way as +ve to P-type and -ve to N-type, it is called forward biasing

At this stage, hole in P-material will be repelled by the positive terminal of the battery and e^- in N-material repelled by -ve terminal of the battery and moves towards the junction

As a result potential barrier get weakened and the width of depletion region reduces.

If the forward V/g is again increased the depletion region is completly eliminated and increase current through the junction. This current is called Forward current

PN-Junction with Reverse bias



When +ve terminal of a battery connected to the N-type and -ve terminal connected to P-type of PN-junction. is known as Reverse bias

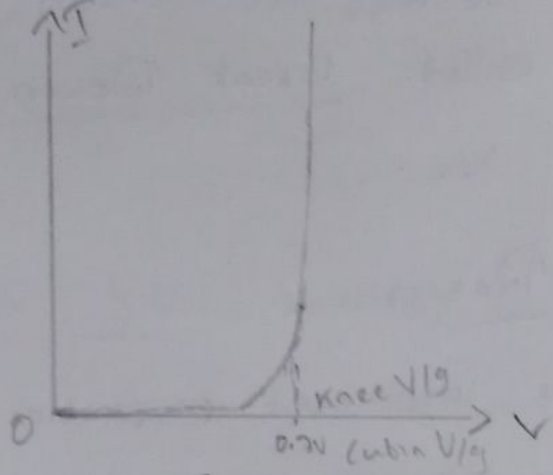
The biasing causes electrons in N-Type get attracted to +ve terminal and holes in P-Type get attracted to -ve terminal of battery. Thus the width of depletion region widens and barrier potential increases.. So practically no current flows through the junction

But it is helpful for minority carriers crossing the PN junction and a small current

exists from N to P region. This current is known as Reverse Saturation Current

VI Characteristics of a Diode

VI chara of a diode represents the relation b/w the applied V/g across junction and current that flows through it



During forward biased condition, the diode will not conduct till barrier V/g by exceeding V/g. The voltage at which current starts to increase rapidly is called CUT IN Voltage or KNEE VOLTAGE

In Reverse bias, a small current known as leakage current or reverse saturation current flows through the diode (2MA for Ge 1OMA for Si)

If reverse bias is increased continuously, the Kinetic Energy of Electron becomes high that they knock out e's from covalent bond. At this stage breakdown occurs and high current will flow through the diode

The voltage at which breakdown occurs is called Break Down Voltage marked as V_z.

Diode Resistance

One of the important properties of the diode is its resistance in the forward and reverse bias condition. An ideal diode offer zero resistance in forward bias and infinite resistance in reverse bias

-> DC or Static Resistance

-> AC or Dynamic Resistance

DC resistance (R_D):

When diode is in forward bias, it offers a resistance called static or DC resistance. It is the ratio of the dc V/g, across the diode to the current flowing through it, at a particular instant

$$R_D = \frac{V_D}{I_D}$$

AC resistance (r_d)

The AC or dynamic resistance of a diode is resistance offered by the diode to an AC signal.

$$r_d = \frac{\text{Change in } V_g}{\text{Change in Current}} = \frac{\Delta V_D}{\Delta I_D}$$

Breakdown in PN Junction

We have seen that a reverse biased PN Junction allows a very small current known as reverse saturation current.

If reverse bias is increased beyond a certain limits, the Breakdown of Crystal occurs. This cause high current to flow through the junction. This may degenerate enough heat to destroy the junction.

There are two process involved in causing junction breakdown in reverse bias.

→ zener breakdown
→ Avalanche Breakdown

Zener breakdown

If the reverse bias voltage across diode is increased beyond a limit, the electric field at junction also increases. This causes covalent bond in the crystal to break. Thus a large no. of charge carriers becomes available. So a large current flows through the junction. This phenomenon is called zener breakdown

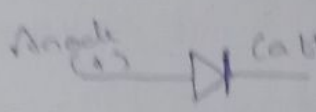
Avalanche breakdown

The high electric field across the junction provide higher value to minority charge carriers. These minority charge carriers aquire energy & break covalent bond, so, more free e⁻ become available. Again the accelerated charge carriers breaks more covalent bonds. This process continues and large no. of free charge carriers become available and cause high reverse current. This phenomenon is known as Avalanche breakdown.

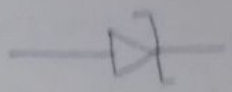
Application of Diode

* Rectifiers in DC power supply
* Switch in Digital circuits
* Wave shaping circuits
* Modulator/De-modulator in TV/Radio

Symbol of Diode



Eg:- IN4007

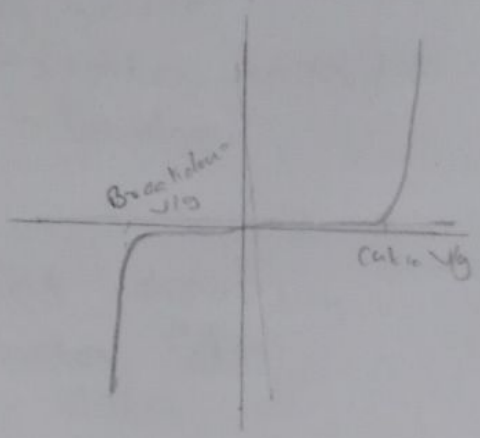
Zener diode - 

Zener diodes also know as breakdown diodes. These are specially doped PN junction diodes to produce controlled breakdown characteristic without damage and are operated in breakdown region.

The mechanism in Zener diode is influenced by two phenomenon. Zener effect and avalanche effect. The Zener effect is predominant for breakdown voltages less than 4 volt and the avalanche breakdown is predominant for voltages greater than 6V. Between 4V and 6V both effect are present.

The Breakdown voltage (V_z) can be controlled by varying the doping level of PN Junction. Increased impurity will ~~dec~~ decrease breakdown voltages.

V-I chara of Zener diode



Here forward chara is similar to an ordinary diode. In Reverse bias when a certain voltage is reached specifically when breakdown $V/g^{(V_z)}$ is reached the current steadily increases. This current is known as Breakdown Current (I_z). When Zener operates this ~~reg~~ region the voltage $-V_z$ across it remains fairly constant even though current is varied.

Application of Zener diode

-> Voltage Regulator
-> Fixed Reference voltage source
-> Wave shaping circuit
-> Over voltage protection