4.1 Definition of Semiconductors

Semi-conductors are neither good conductors nor good insulators, but belong to a class of material between the two.

The semiconductor materials are :

- Germanium (Ge)
- Silicon (Si)

4.2 Intrinsic Semiconductor

Intrinsic semiconductors are pure Germanium or Silicon crystal.

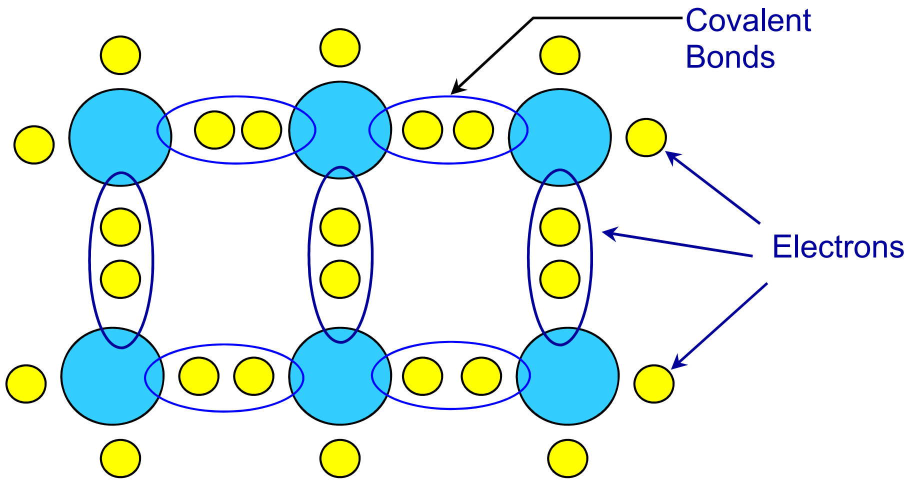
An atom needs 8 electrons on the outermost shell to be stable.

Germanium and Silicon atoms have 4 valence electrons on the outmost shell (valence shell).

Hence by forming covalent bond with other atoms of the same material, it results in a stable crystalline structure.

4.3 Covalent Bond

It is the sharing of electrons with neighbouring atoms in order to fill its outer shell with 8 electrons.



4.4 Holes

Each time, an electron breaks away from a covalent bond, a hole is created.

A hole represents the absence of an electron in a covalent bond.

The hole acts like a positive charge because it will attract and capture any free electron that happens to come near it.

A hole (positive charge) can attract adjacent bound electron. When the adjacent bound electron move to fill up the hole, the hole at the original position disappears.

But a new hole is created at that adjacent bound electron when it moves out of its shell.

In this way, a hole can move from one atom to another atom.

4.5 Doping

It is the process of adding controlled amount of impurities to pure semiconductor to improve conductivity.

4.6 Extrinsic Semiconductor

A semiconductor that has been doped is called an extrinsic semiconductor.

There are 2 types of extrinsic semiconductor, namely:

- N - type semiconductor
- P- type semiconductor

4.7 N – Type Semiconductor

By doping the pure crystal with pentavalent (donors) impurities, that is, a material with 5 valence electrons, we get N – type semiconductor.

Examples of pentavalent impurities are :

- Antimony (Sb)
- Arsenic (As)
- Phosphorous (P)

Only free electrons are produced by doping with pentavelent impurities.

As a result, for N –type semiconductor, there are more free electrons than holes.

Hence, the majority carriers are the free electrons and the minority carriers are the holes as shown in Fig 4.7

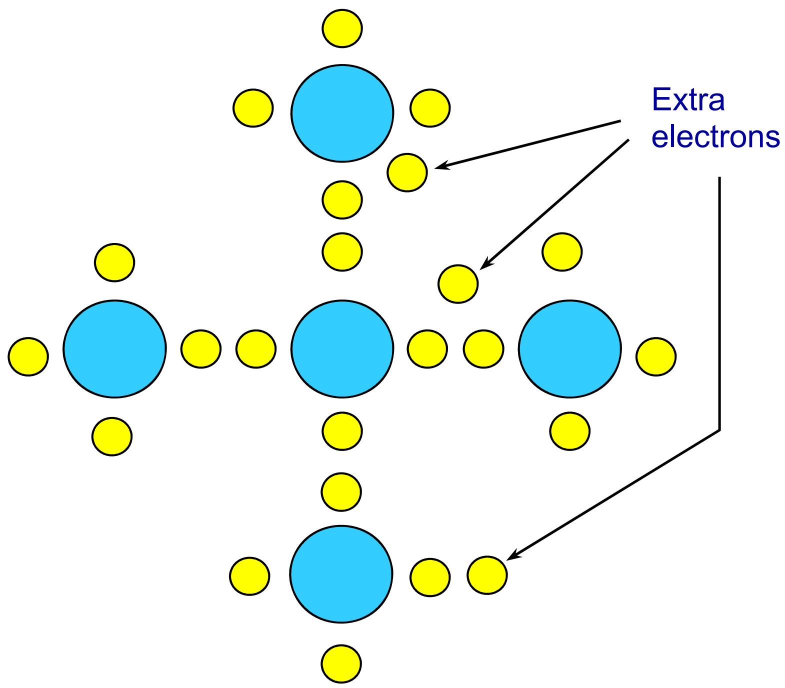


Fig 4.7

4.8 P – Type Semiconductor

By doping the pure crystal with trivalent (acceptors) impurities, that is, material having 3 valence electrons, we get P-type semiconductor.

Examples of trivalent impurities are :

- Aluminium (A1)
- Boron (B)
- Gallium (Ga)
- Indium (In)

Only the holes are produced by doping with trivalent impurities.

As a result, for P-type semiconductor, there are more holes than free electrons.

Hence, the majority carriers are the holes and the minority carriers are the free electrons as shown in Fig 4.8.

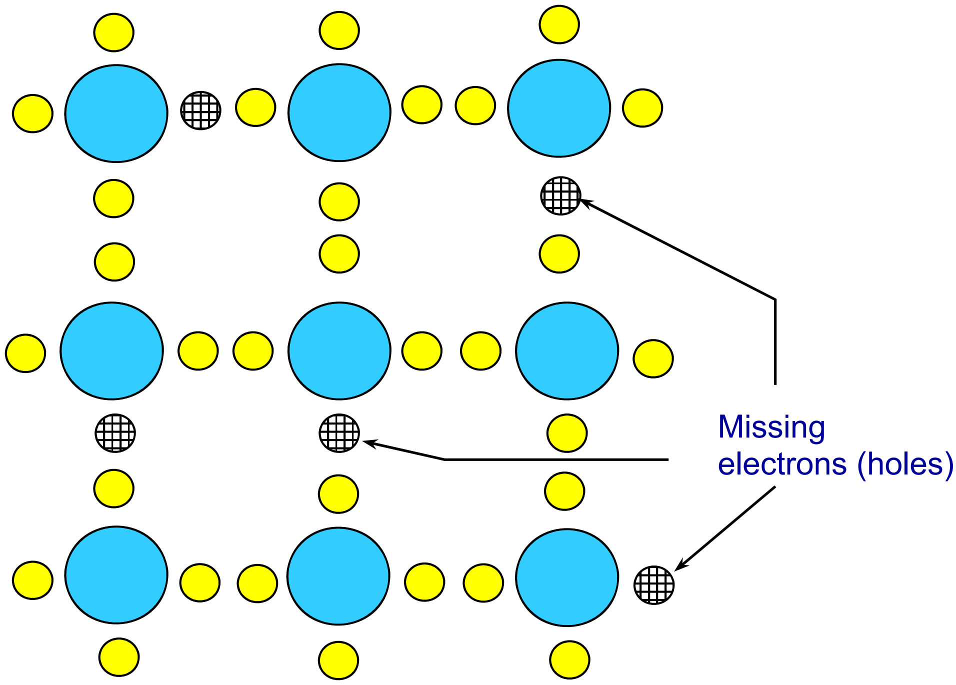


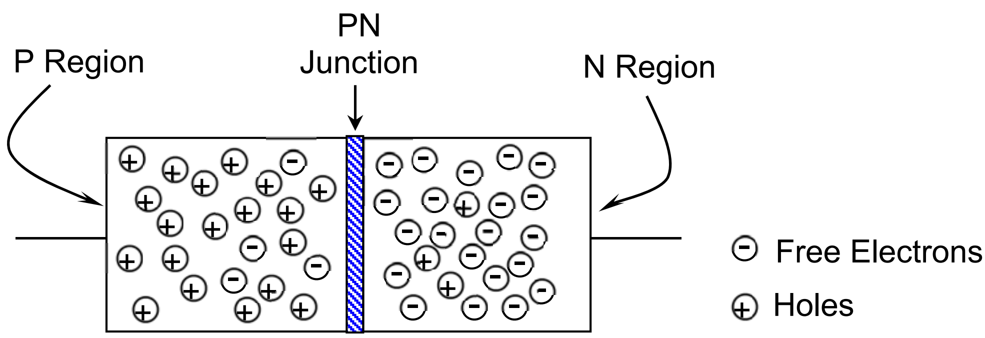
Fig 4.8

4.9 Definition of PN Junction Diode

A diode is made by joining P- type and N-type materials.

The junction of a diode is the region where the P-type material ends and the N-type material begin as shown in Fig 4.9.

Diagram



Symbol

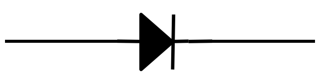


Fig 4.9

4.10 Depletion region

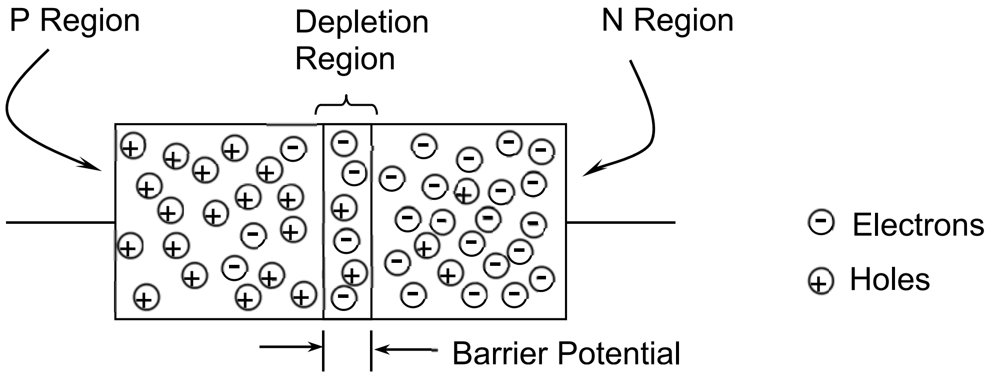
At the instant when junction is formed, diffusion takes place. That is, some holes will move from the P-type material into the N-type material.

Likewise some electrons will move from the N-type material into the P- type materials.

These holes and free electrons, which move across the junction, recombine and produce a depletion region at the junction.

The depletion region is where there is no mobile majority charge carrier.

It contains positively and negatively charged atoms on either sides of the junction.



4.11 Barrier Potential Difference (or Barrier Voltage)

The opposite charges that build up on each side of the junction create a barrier voltage or potential barrier which resists any further free electrons and holes from crossing the junction.

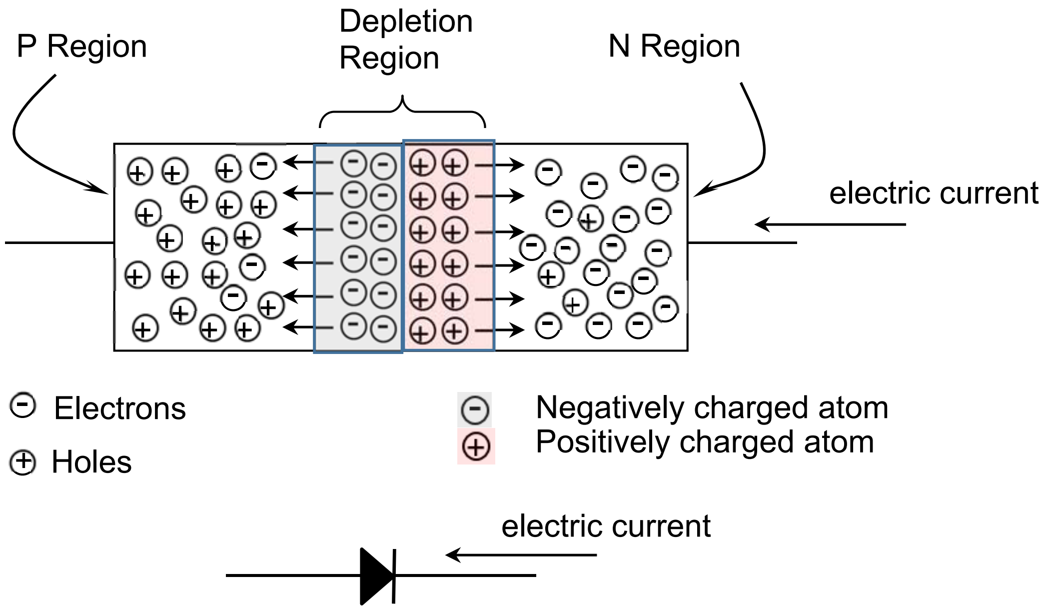
The barrier voltage is about 0.3V for a Germanium junction and 0.7V for a silicon junction.

4.12 Reverse Bias

When P-type material is connected to the negative terminal of the supply and the N-type material is connected to the positive terminal of the supply, the diode is said to be reverse biased.

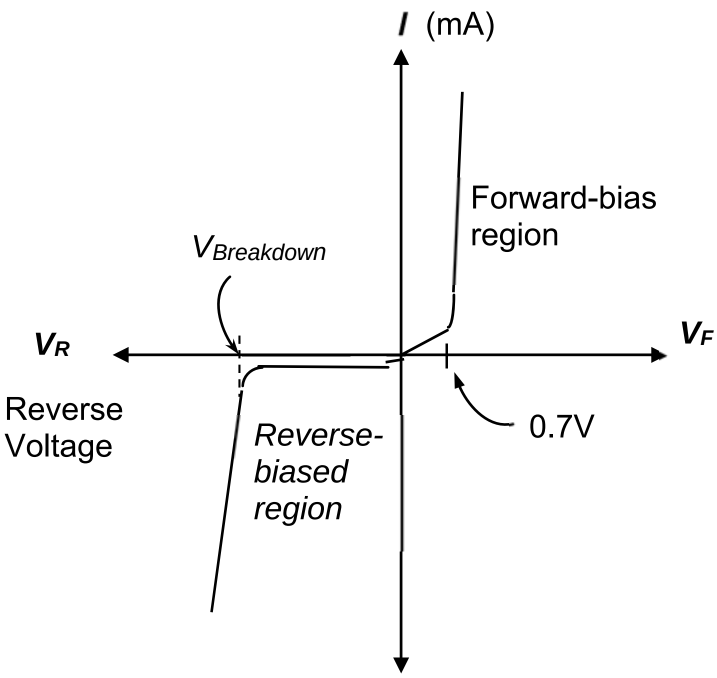
The external voltage supply causes the majority carriers, holes from P-type material and electrons from N-type material to move away from the junction.

As a result, the depletion region at the junction becomes larger.



<u>Reversed Biased Diode</u>

4.13 Diode Reverse and Forward Bias Characteristics Curve



When the diode is reversed-biased, a very small current (due to the minority carriers) called the reverse current or leakage current will flow only.

This means that, the reverse biased resistance of the diode is very high.
When the reverse bias voltage is high enough, it will cause damage or breakdown PN junction.
This reverse voltage is called the breakdown voltage.

For any diode, the Peak Inverse Voltage (PIV) is the maximum safe reverse voltage of a diode specified by the manufacturer.

4.14 Forward Bias

When the P-type material is connected to the positive terminal of the supply and the N-type material is connected to the negative terminal of the supply, the diode is said to be forward biased.

The potential of the external supply forces holes from P-type material and electrons from N-type material to cross the junction.

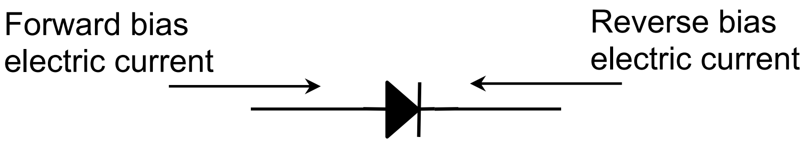
A large current called the forward current flows through the diode.

4.15 Diode Forward Bias Characteristic Curve

When the amount of forward bias voltage equals the barrier voltage, there is no longer any depletion region and the junction can conduct current.

This barrier potential difference, V_F is 0.3V for Germanium diode and 0.7V for Silicon diode.

4.16 Characteristics of a Diode



The anode is the P-type material of the diode. The cathode is the N-type material of the diode.

A diode is a non-linear device. When it is forward biased, current flows through it easily since it acts as a very low resistance.

When the diode is forward biased, it acts as a closed switch in series with a small forward voltage (0.7V for Silicon) as shown in Fig 4.16(a).

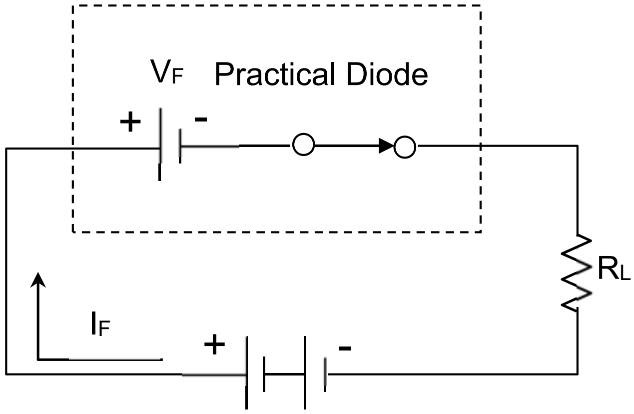


Fig 4.16(a)

When it is reverse biased, current does not flow through it since it now acts as a very high resistance.

When the diode is reverse biased, it acts as an open switch as shown in Fig 4.16(b)

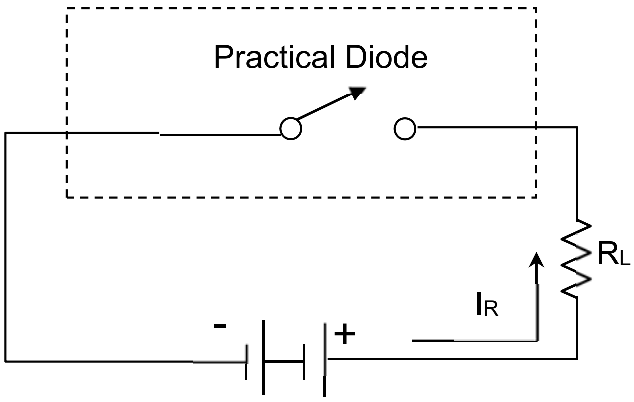


Fig 4.16(b)

4.17 Diode Rating

Diodes are generally rated by its voltage, current or power.

4.18 Peak Inverse Voltage (PIV)

It is define as the maximum reverse bias voltage that can be applied to a diode without the diode breaking down.

4.19 Maximum Forward Current Rating

It is referred to the maximum current that is allowed to flow through the diode.

4.20 PN Junction Diode's Specification Sheet

A manufacturer's specification sheet or data sheet is a document that summarizes the technical characteristics and maximum and minimum values of operation for a given device.

As a technician, he/she could isolate component malfunction within a circuit by determining whether the device is operating to specification.

Example

Would any of the maximum ratings of IN4002 diode in Fig 4.20 (a) be exceeded?

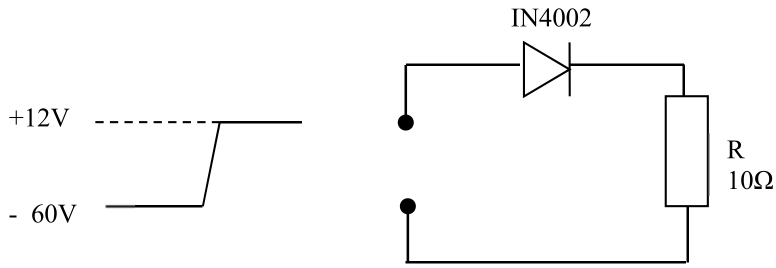


Fig 4.20 (a)

Solution:
The maximum reverse voltage for IN4002 is 100V, and since reverse voltage is not being exceeded by the applied voltage, the diode is being operated within specification.

The maximum forward current will be:

$$I = \frac{V_s - V_{diode}}{R}$$

$$I = \frac{12V - 1.0V}{10\Omega} = 1.1A$$

Since this is in excess of the 1A maximum listed in the data sheet, the diode will more likely burn out due to excessive current.

1N4001 - 1N4007

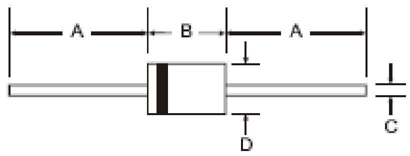
1.0A RECTIFIER

Features

- Diffused Junction
- High Current Capability and Low Forward Voltage Drop
- Surge Overload Rating to 30A Peak
- Low Reverse Leakage Current
- **Lead Free Finish, RoHS Compliant (Note 3)**

Mechanical Data

- Case: DO-41
- Case Material: Molded Plastic. UL Flammability Classification Rating 94V-0
- Moisture Sensitivity: Level 1 per J-STD-020D
- Terminals: Finish - Bright Tin. Plated Leads Solderable per MIL-STD-202, Method 208
- Polarity: Cathode Band
- Mounting Position: Any
- Ordering Information: See Page 2
- Marking: Type Number
- Weight: 0.30 grams (approximate)



Dim	DO-41 Plastic	
	Min	Max
A	25.40	—
B	4.06	5.21
C	0.71	0.864
D	2.00	2.72
All Dimensions in mm		

The **Peak Repetitive Reverse Voltage** is the maximum allowable reverse voltage . This rating is also called **Working Peak Reverse Voltage** and **PIV**.

Maximum Ratings and Electrical Characteristics @T_A = 25°C unless otherwise specified

Single phase, half wave, 60Hz, resistive or inductive load.
For capacitive load, derate current by 20%.

Characteristic	Symbol	1N4001	1N4002	1N4003	1N4004	1N4005	1N4006	1N4007	Unit
Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	V_{RRM} V_{RWM} V_R	50	100	200	400	600	800	1000	V
RMS Reverse Voltage	$V_{R(RMS)}$	35	70	140	280	420	560	700	V
Average Rectified Output Current (Note 1) @ T_A = 75°C	I_O	1.0							A
Non-Repetitive Peak Forward Surge Current 8.3ms single half sine-wave superimposed on rated load	I_{FSM}	30							A
Forward Voltage @ I_F = 1.0A	V_{FM}	1.0							V
Peak Reverse Current @T_A = 25°C at Rated DC Blocking Voltage @ T_A = 100°C	I_{RM}	5.0 50							µA
Typical Junction Capacitance (Note 2)	C_j	15				8			pF
Typical Thermal Resistance Junction to Ambient	$R_{\theta JA}$	100							K/W
Maximum DC Blocking Voltage Temperature	T_A	+150							°C
Operating and Storage Temperature Range	T_J, T_{STG}	-65 to +150							°C

The maximum average forward current value

The voltage drop value that will appear across the diode when forwad biased.

The diode can operated and stored at any temperature between -65° to +175°C.

Fig 4.20 (b) Specific Data Sheet for IN4001 through IN4007 Junction Diodes.