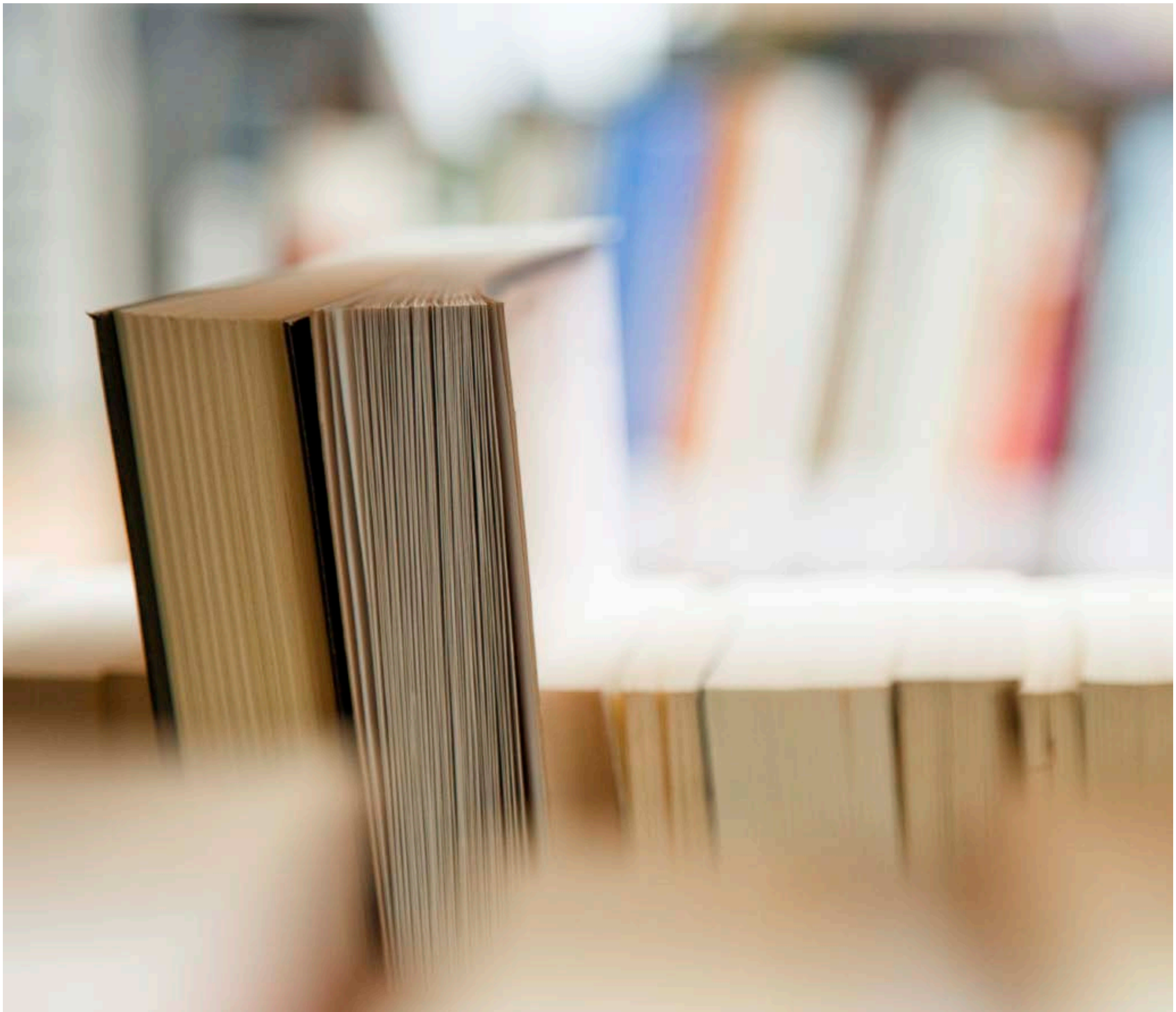

Electronic
Second Stage

M.Sc. Zahraa Niema Kamal First Course Lecture One

Lecture One

Semiconductor Materials and PN Junction Diode

1.1 Introduction to Materials

- The term conductor is applied to any material that will support a generous flow of charge when a voltage source of limited magnitude is applied across its terminals.
- An insulator is a material that offers a very low level of conductivity under pressure from an applied voltage source.
- A semiconductor, therefore, is a material that has a conductivity level somewhere between the extremes of an insulator and conductor.

Most of the electronic devices are made from semiconductor material because the energy levels of a semiconductor can be modified so that a material (e.g. silicon or germanium) that is normally an insulator will conduct electricity (see Fig. 1). Energy level structure of a semiconductor is quite complicated, requires a quantum mechanical treatment.

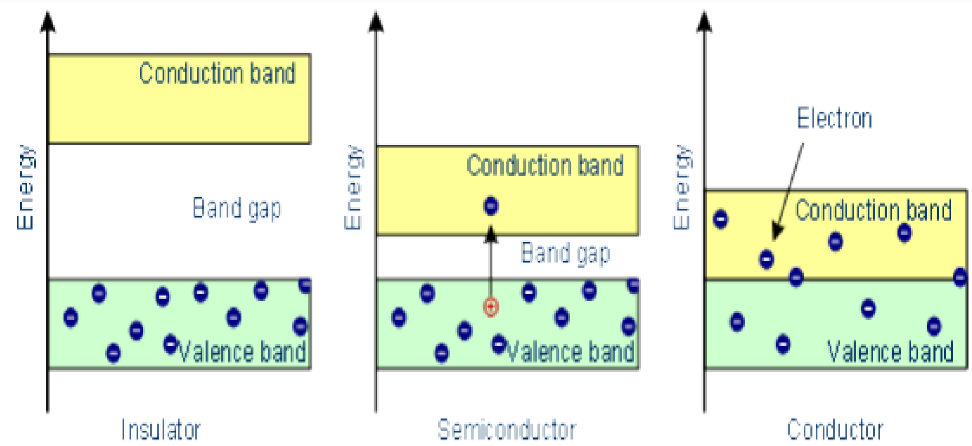

Fig. 1: Energy band gaps in materials.

1.2 Intrinsic Semiconductors

Intrinsic materials are those semiconductors that have been carefully refined to reduce the impurities to a very low level essentially as pure as can be made available through modern technology.

- The free electrons in the material due only to natural causes are referred to as intrinsic carriers.
- An increase in temperature of a semiconductor can result in a substantial increase in the number of free electrons in the material.
- A bonding of atoms, strengthened by the sharing of electrons, is called covalent bonding.
- The covalent bonding process in Silicon (Si) is illustrated in Fig. 2.

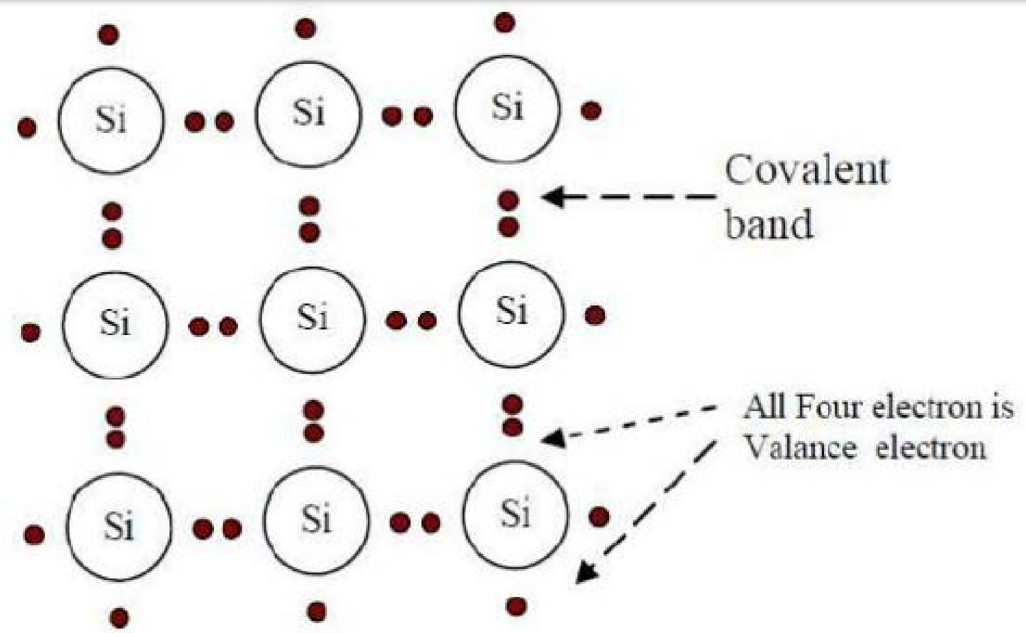

Fig. 2: Silicon structure.

1.3 Extrinsic Semiconductors

A semiconductor material that has been subjected to the doping process is called an extrinsic material.

- Doping: is a process where impurities are added to the semiconductor to lower its resistivity.
- Silicon has 4 electrons in its valence level.
- We add atoms which have a different number of valence shell electrons 3 or 5 to a piece of silicon to build P-Type or N-Type silicon structure, respectively.
- Phosphorous, Arsenic and Antimony have 5 valence electrons.
- Boron, Aluminum and Indium have 3 valence electrons.

1.4 N-Type Semiconductor

Adding atoms which have 5 valence electrons makes the silicon more negative. The majority carriers are the excess electrons as shown in Fig. 3.

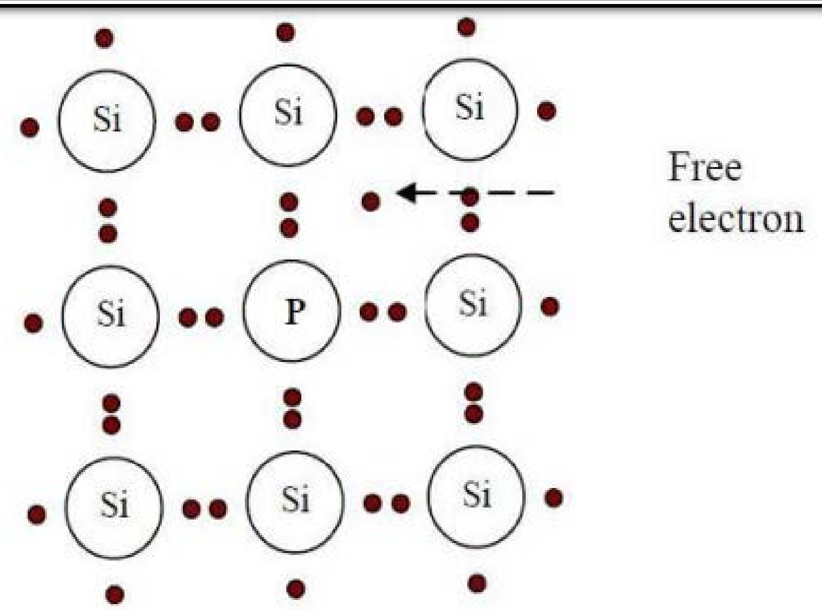

Fig. 3: N-Type semiconductor.

1.5 P-Type Semiconductor

Adding atoms which have 3 valence electrons makes the silicon more positive. The majority carriers are "holes" and the minority carriers are electrons as shown in Fig. 4. A hole is the lack of an electron in the valence shell.

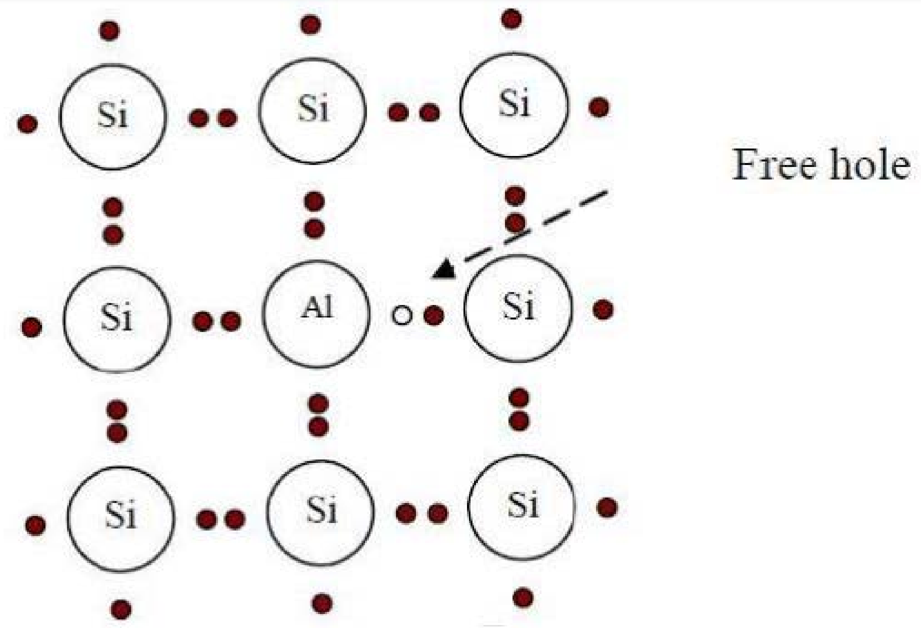

Fig. 4: P-Type semiconductor.

1.6 The PN Junction

When you take a block of silicon and dope part of it with a trivalent impurity and the other part with a pentavalent impurity, a boundary called the PN junction is formed between the resulting p-type and n-type portions. The PN junction is the basis for diodes, certain transistors, solar cells, and other devices. If a piece of intrinsic silicon is doped so that part is n-type and the other part is p-type, a PN junction forms at the boundary between the two regions and a diode is created, as indicated in Fig. 5a.

The p region has many holes (**majority carriers**) from the impurity atoms and only a few thermally generated free electrons (**minority carriers**). The n region has many free electrons (**majority carriers**) from the impurity atoms and only a few thermally generated holes (**minority carriers**).

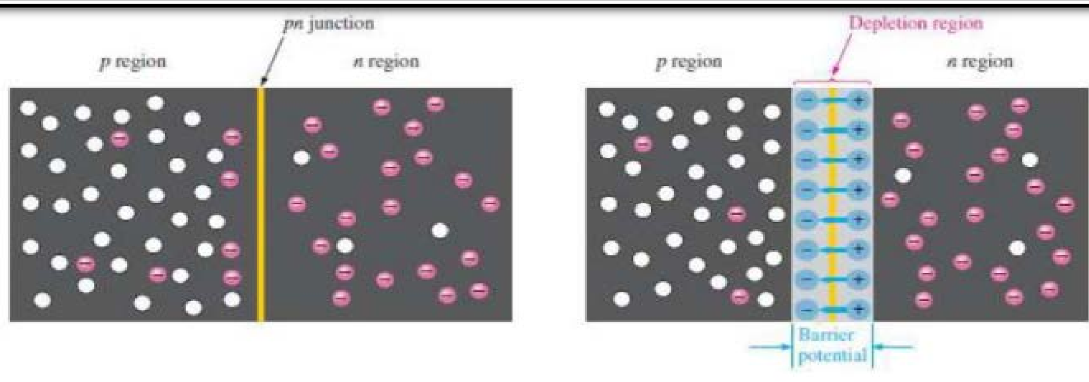

Fig. 5: (a) PN junction, (b) Depletion region.

1.7 Formation of the Depletion Region

The free electrons in the n region are randomly drifting in all directions. At the instant of the PN junction formation, the free electrons near the junction in the n region begin to diffuse across the junction into the p region where they combine with holes near the junction, as shown in Fig. 5 b. Before the PN junction is formed, recall that there are as many electrons as protons in the n-type material, making the material neutral in terms of net charge. The same is true for the p-type material. When the PN junction is formed, the n region loses free electrons as they diffuse across the junction. This creates a layer of positive charges near the junction.

As the electrons move across the junction, the p region loses holes as the electrons and holes combine. This creates a layer of negative charges near the junction. These two layers of positive and negative charges form the depletion region, as shown in Fig. 5 b. The term depletion refers to the fact that the region near the pn junction is depleted of charge carriers (electrons and holes) due to diffusion across the junction. The depletion region is formed very quickly and is very thin compared to the n region and p region.

1.8 Barrier Potential

Any time there is a positive charge and a negative charge near each other, there is a force acting on the charges as described by Coulomb's law. In the depletion region there are many positive charges and many negative charges on opposite sides of the PN junction. The forces between the opposite charges form an electric field, as illustrated in Fig. 5 b by the arrows between the positive charges and the negative charges. This electric field is a barrier to the free electrons in the n region, and energy must be expended to move an electron through the electric field. That is, external energy must be applied to get the electrons to move across the barrier of the electric field in the depletion region. The potential difference of the electric field across the depletion region is the amount of voltage required to move electrons through the electric field. This potential difference is called the barrier potential and is expressed in volts. The barrier potential of a PN junction depends on several factors, including the type of semiconductive material, the amount of doping, and the temperature. The typical barrier potential is approximately 0.7 V for silicon and 0.3 V for germanium at 25°C.

1.9 The Diode Symbol

The lead attached to the n-type semiconductor is called the cathode. Thus, the cathode is the negative side of the diode. The positive side of the diode that is, the lead attached to the p-type semiconductor is called the anode. When a voltage source is connected to a diode such that the positive side of the voltage source is on the anode and the negative side is on the cathode, the diode becomes a conductor and allows current to flow. Voltage connected to the diode in this direction is called forward bias. But if you reverse the voltage direction, applying the positive side to the cathode and the negative side to the anode, current doesn't flow. In effect, the diode becomes an insulator. Voltage connected to the diode in this direction is called reverse bias.

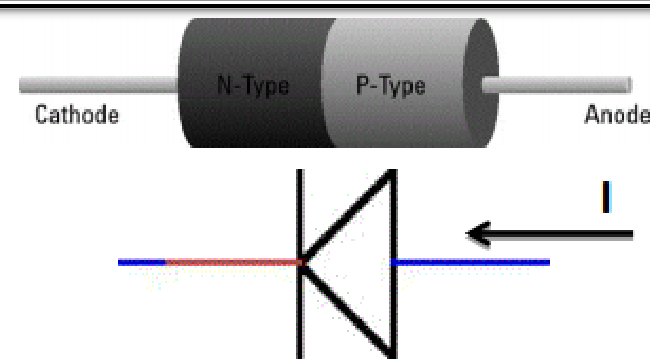

Fig. 6: The schematic symbol for the diode.

1.10 Types of Diodes

There are many types of diodes for many applications as:

1- Junction diode (ordinary type).
2- Light Emitting Diode (LED).
3- Photodiodes (absorbs light, gives current).
4- Schottky diode (high speed switch).
5- Tunnel diode.
6- Veractor diode (varies with voltage).
7- Zener diode (special junction diode, use reversed biased).