AL-Mustaqbal University College
Department of Medical Physics
The Second Stage
Semiconductors
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أشباه موصلات

Lecture .2

Energy Bands Description

In gaseous substances, the arrangement of molecules are spread apart and are not so close to each other. In liquids, the molecules are closer to each other. But, in solids, the molecules are closely arranged together, due to this the atoms of molecules tend to move into the orbitals of neighbouring atoms. Hence, the electron orbitals overlap when atoms come together.

In solids, several bands of energy levels are formed due to the intermixing of atoms in solids. We call these set of energy levels as **energy bands**.

Formation of Energy Bands

In an isolated atom, the electrons in each orbit possess definite energy. But, in the case of solids, the energy level of the outermost orbit electrons are affected by the neighbouring atoms.

When two isolated charges are brought close to each other, the electrons in the outermost orbit experiences an attractive force from the nearest or neighbouring atomic nucleus. Due to this reason, the energies of the electrons will not be at the same level, the energy levels of electrons are changed to a value which is higher or lower than that of the original energy level of the electron.

The electrons in the same orbit exhibit different energy levels. The grouping of this different energy levels is known as energy band.

However, the energy of the inner orbit electrons are not much affected by the presence of neighbouring atoms.

Classification of Energy Bands

Valence Band

The electrons in the outermost shell are known as valence electrons. These valence electrons contain a series of energy levels and form an energy band known as valence band. The valence band has the highest occupied energy.

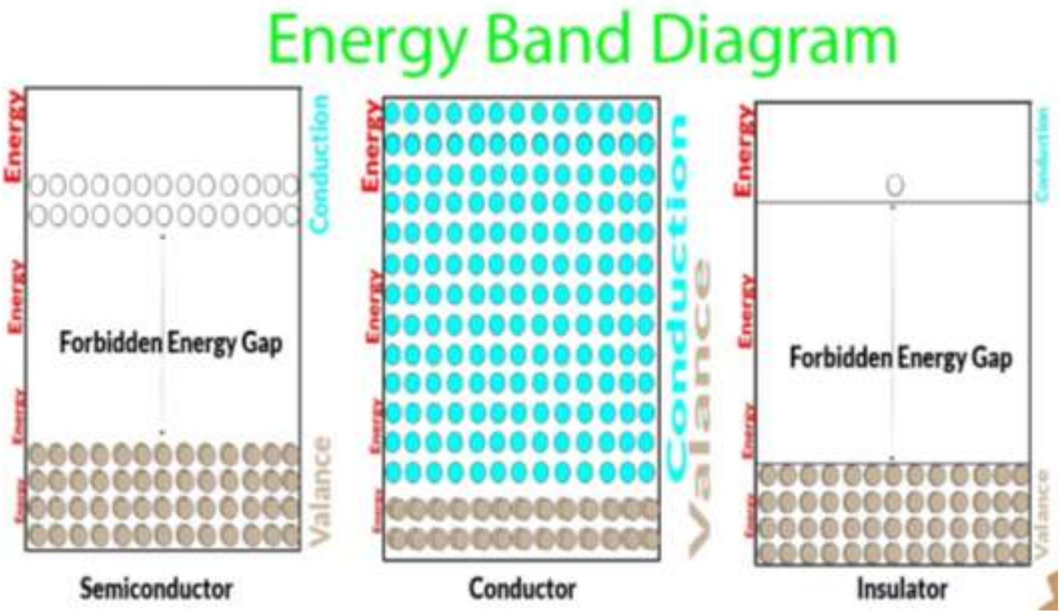
Conduction Band

The valence electrons are not tightly held to the nucleus due to which a few of these valence electrons leave the outermost orbit even at room temperature and become free electrons. The free electrons conduct current in conductors and are therefore known as conduction electrons. The conduction band is one that contains conduction electrons and has the lowest occupied energy levels.

Forbidden Energy Gap

The gap between the valence band and the conduction band is referred to as forbidden gap. As the name suggests, the forbidden gap doesn’t have any energy and no electrons stay in this band. If the forbidden energy gap is greater, then the valence band electrons are tightly bound or firmly attached to the nucleus. We require some amount of external energy that is equal to the forbidden energy gap.

The figure below shows the conduction band, valence band and the forbidden energy gap.



(Fig .1) Insulators, semiconductors and conductors are formed based on the size of the forbidden gap

Conductors

Gold, Aluminium, Silver, Copper, all these metals allow an electric current to flow through them.

There is no forbidden gap between the valence band and conduction band which results in the overlapping of both the bands. The number of free electrons available at room temperature is large.

Insulators

Glass and wood are examples of the insulator. These substances do not allow electricity to pass through them. They have high resistivity and very low conductivity.

The energy gap in the insulator is very high up to 7eV. The material cannot conduct because the movement of the electrons from the valence band to the conduction band is not possible.

Semiconductors

Germanium and Silicon are the most preferable material whose electrical properties lie in between semiconductors and insulators. The energy band diagram of semiconductor is shown where the conduction band is empty and the valence band is completely filled but the forbidden gap between the two bands is very small that is about 1eV. For Germanium, the forbidden gap is 0.72eV and for Silicon, it is 1.1eV. Thus, semiconductor requires small conductivity.

Energy Band Theory

According to Bohr's theory, every shell of an atom contains a discrete amount of energy at different levels. Energy band theory explains the interaction of electrons between the outermost shell and the innermost shell. Based on the energy band theory, there are three different energy bands:

1. Valence band
2. Forbidden energy gap
3. Conduction band

Frequently Asked Questions

1-The valence band and the conduction band overlap in _____.

The valence band and the conduction band overlap in conductors.

2-What is the energy that a valence electron should have to jump from valence band to conduction band called?

The valence electrons must have the same energy as an energy gap to jump from valence band to conduction band.

3-What is the energy gap between the valence and conduction band termed as?

The energy gap between the valence and the conduction band is termed as energy gap.

4-The band in which the electrons move freely is known as _____.

The band in which the electrons move freely is known as conduction band.

5-What is a band model?

Band theory models the behaviour of electrons in solids by postulating the existence of energy bands. It successfully uses a material's band structure to explain many physical properties of solids.

Doping in Semiconductor Material

In the previous paragraphs, we talked about the most important features of semiconductors:

The current passing through it can be controlled through the process of doping, and the doping process is: the process in which impurities of certain elements are added to the pure semiconductor (intrinsic), in order to increase the electrical conductivity of the semiconductor, by increasing Current carriers: electrons and holes.

This process results in two types of impure semiconductors (extrinsic):

(N-type) and (p-type semiconductors), depending on the type of impurities added, which are the basic building blocks of most electronic devices.

Now we will take a closer look at each of these two types. We will start with (N-Type Semiconductor), and the letter (N) symbolizes the negative charge on an electron.

In order to increase the number of free electrons in a semiconductor material (we take silicon as an example), we will take pentavalent elements, meaning: its last orbit contains five electrons, which are added, such as phosphorous and arsenic.

Where four electrons from each atom of these elements are linked to the four electrons in the last orbit of the silicon atom with covalent bonds, and thus one electron remains from the atom of the pentavalent element without any bonds, and it turns into a free electron, and that pentavalent atom that is added is called: (**donor atom).**

<u>Majority and Minority Carriers:</u>

In this type of semiconductor (N_type), the majority of the charge carriers are the electrons, because they contain a large number of free electrons (due to the addition of the pentavalent atom), and the minority charge carriers are the holes, which resulted - as we mentioned in the previous article - due to the energy thermal.

Now that we have clarified what is meant by (N-Type Semiconductor), it is the turn of the other type of semiconductor that results from the grafting process, which is: p-type semiconductors:

This type of semiconductor is produced by adding atoms of trivalent elements such as: (boron and gallium) to the pure semiconductor, where the three valence electrons are linked to three of the electrons of the silicon atom by covalent bonds, thus leaving the fourth valence electron of the silicon atom without bonding As a result, there is a gap through which the current can be transmitted. The number of holes in this type of semiconductor can be controlled by controlling the number of trivalent atoms added. This added atom is called the **Acceptor atom**

In this type of semiconductor, the majority of the charge carriers are: holes - because they contain a large number of them - and the minority charge carriers are: the electrons, which are produced from thermal energy

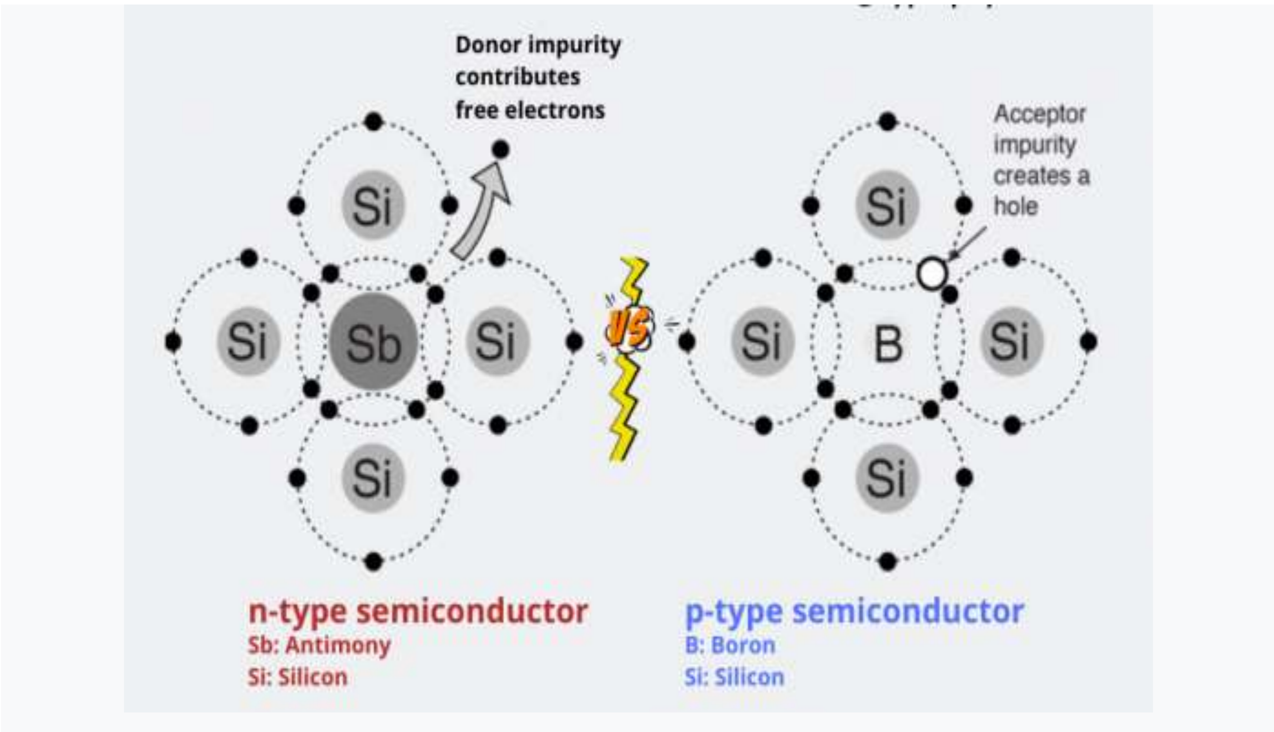


Fig (2) Structure of n-type and p-type semiconductors

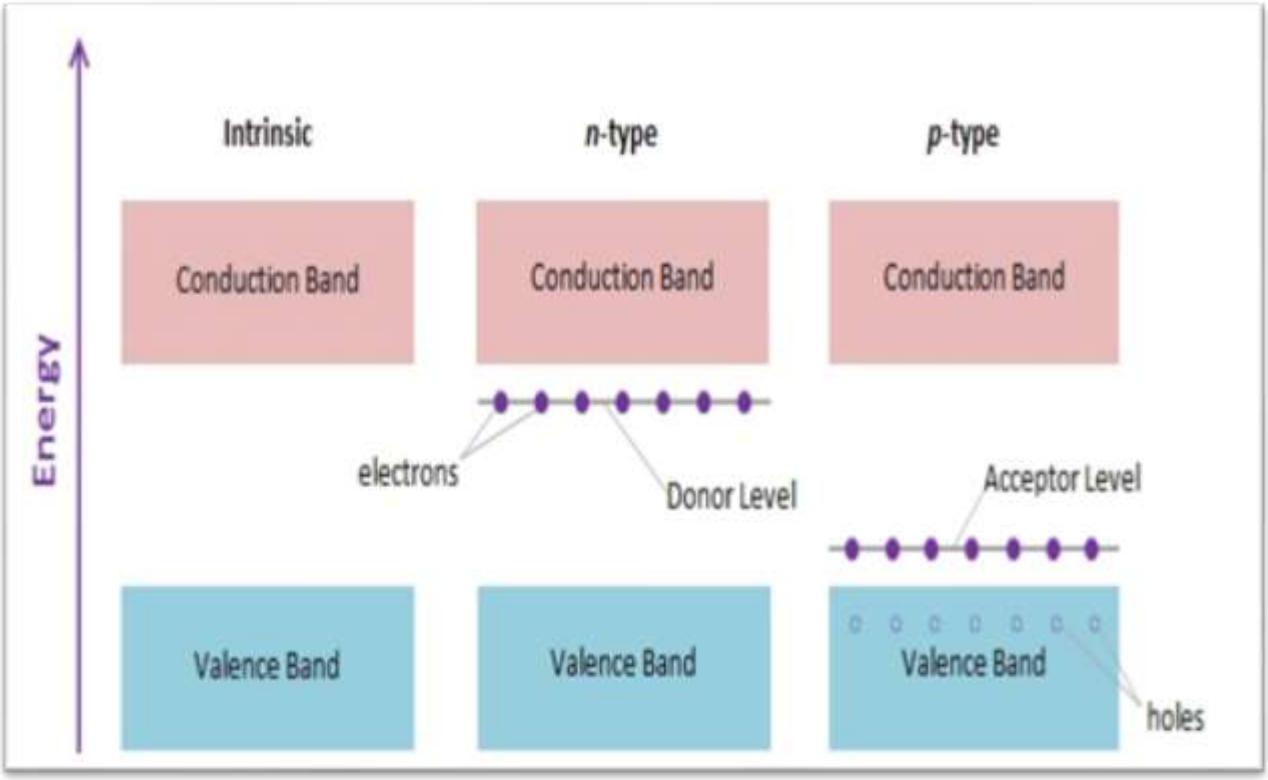


Fig (3) Donor and acceptor levels in n-type and p-type semiconductors

Comparison between n-type and p-type semiconductors

N-type

- Pentavalent impurities are added.
- Majority carriers are electrons.
- Minority carriers are holes.
- Fermi level is near the conduction band.

P-type

- Trivalent impurities are added.
- Majority carriers are holes.
- Minority carriers are electrons.
- Fermi level is near the valence band.