Energy Bands in Solids

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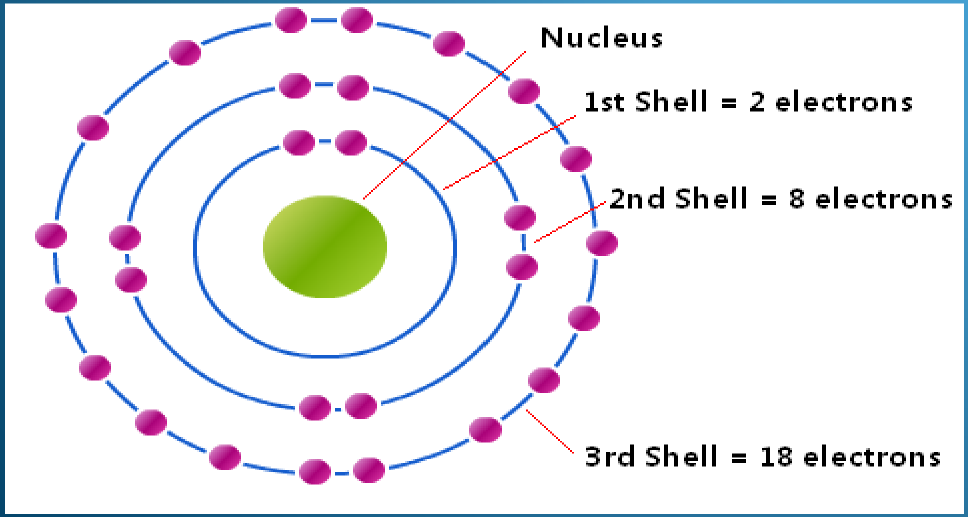
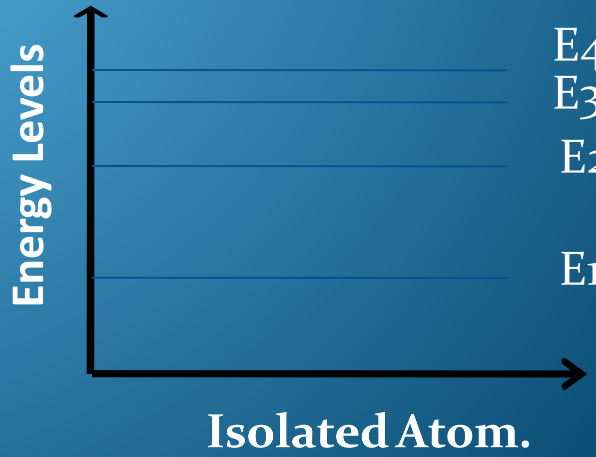
Energy Levels

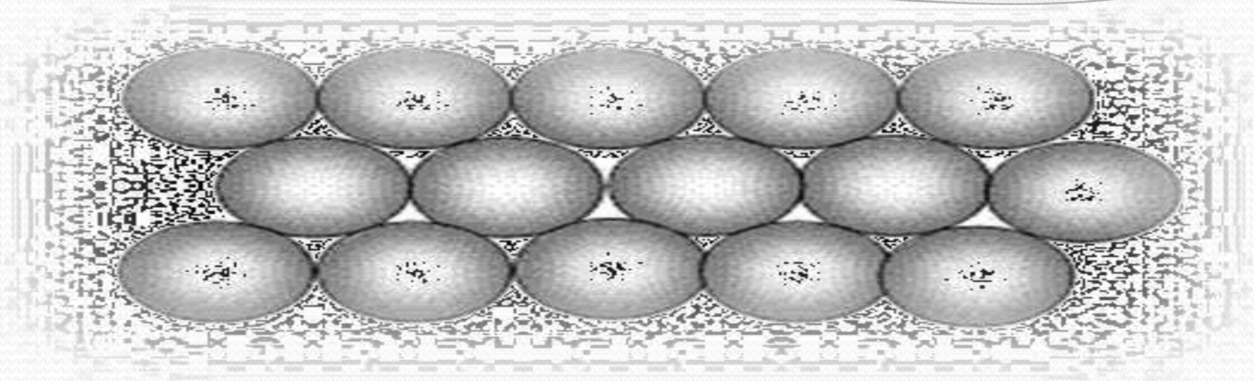
- Electrons of any atom found in specific shells/orbits and have certain orbital radii ; hence certain values of energy.

- These certain values of energy of electrons in an atom are called the energy levels of the atom.

- The energy levels of an isolated single atom are well defined usually represented by series of horizontal lines.





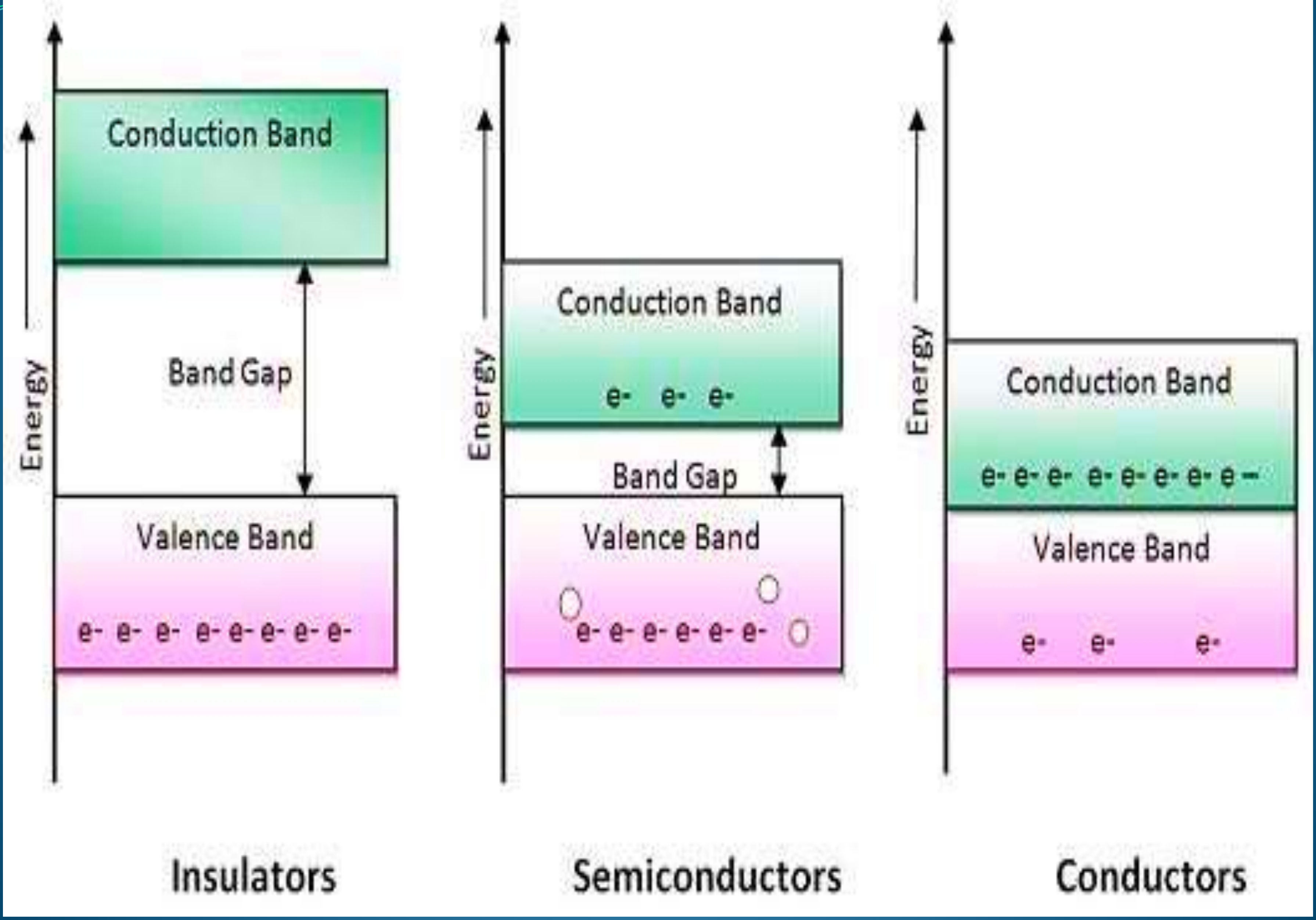


- When two or more, single or isolated atoms are brought close to one another than the electrons in the outermost orbit of one atom experience an attractive force from the neighboring atomic nucleus or repulsive force from the neighboring atom's electrons.
- Due to this, the energies of the electrons 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 called **energy band**.

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

Energy Bands in Solids



Valence Bands

- The electrons in the outermost shell of an atom are called valance electrons. Therefore, the energy band occupied by valance electrons is called the valance band.

- The valance band may be either completely filled or partially filled with the electrons but can never be empty.

Band Gap/Forbidden Bands

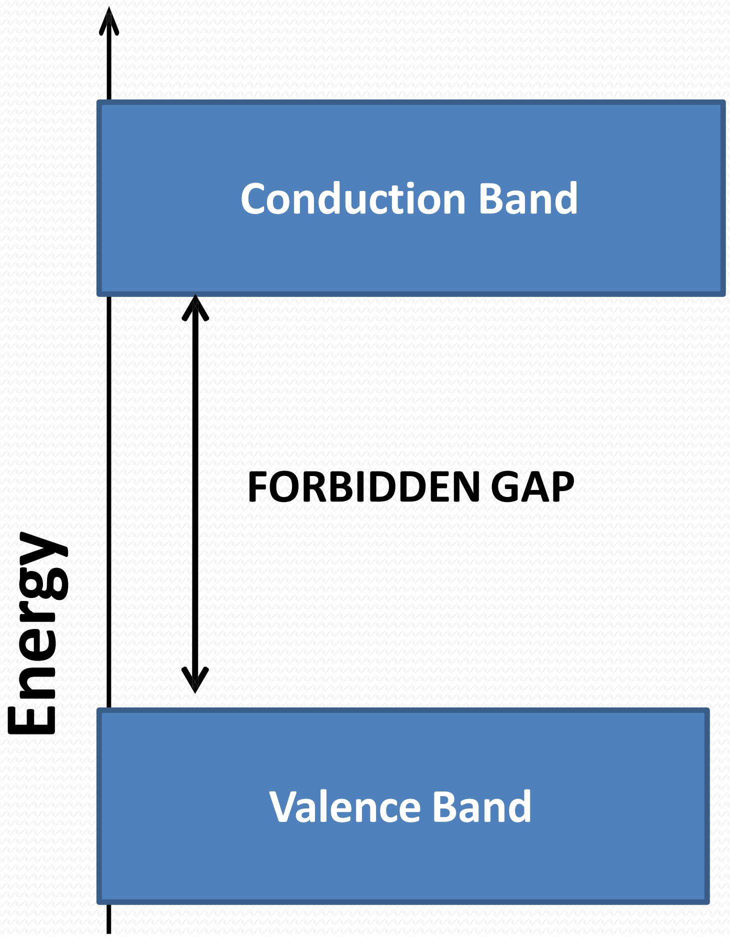
- The energy bands are separated by gaps in which there is no energy level. Such energy gaps are called forbidden bands.
- The electron may jump from one energy band to another by acquiring energy equal to the energy of forbidden energy gap.

Conduction Band

- The energy band next to the valance band is called the conduction band.
- The valance and conduction bands are separated by forbidden energy gaps.
- The conduction band may be empty or partially filled.
- The electrons in the conduction band can drift freely in the materials and are called free or conduction electrons.
- The width of forbidden energy gap between valance and conduction band decide whether a material is a conductor, insulator or a semiconductor.

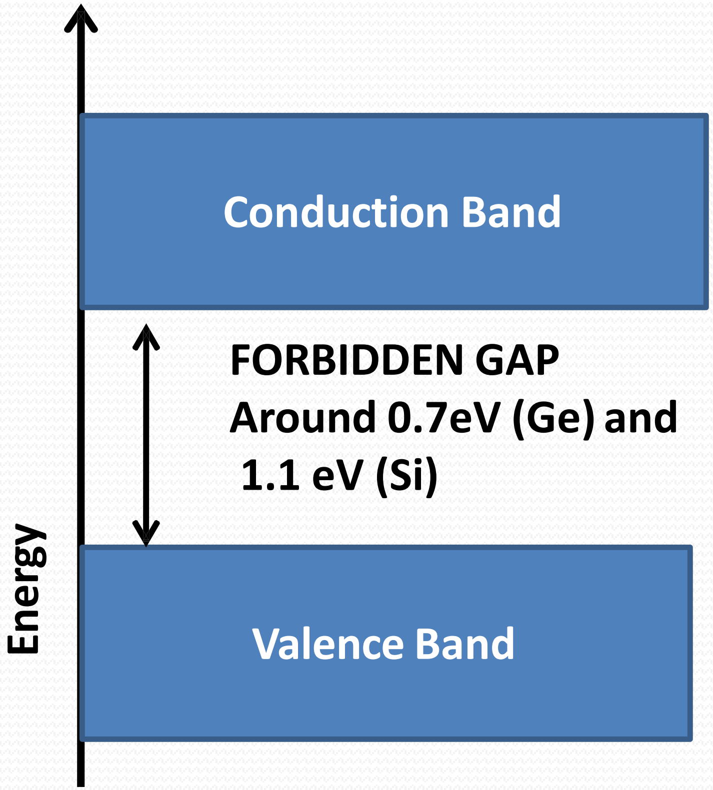
Distinction between Insulators, Semiconductors and Conductors on the basis of Band Theory of Solids

Insulators



- In an insulator, the forbidden gap is very large and in general is more than 3eV.
- No electron is available for conduction.
- Large amount of energy is needed to move electron from valance band to conduction band.
- As there are no free electrons in insulator, hence no current can pass through insulators.

Semiconductors

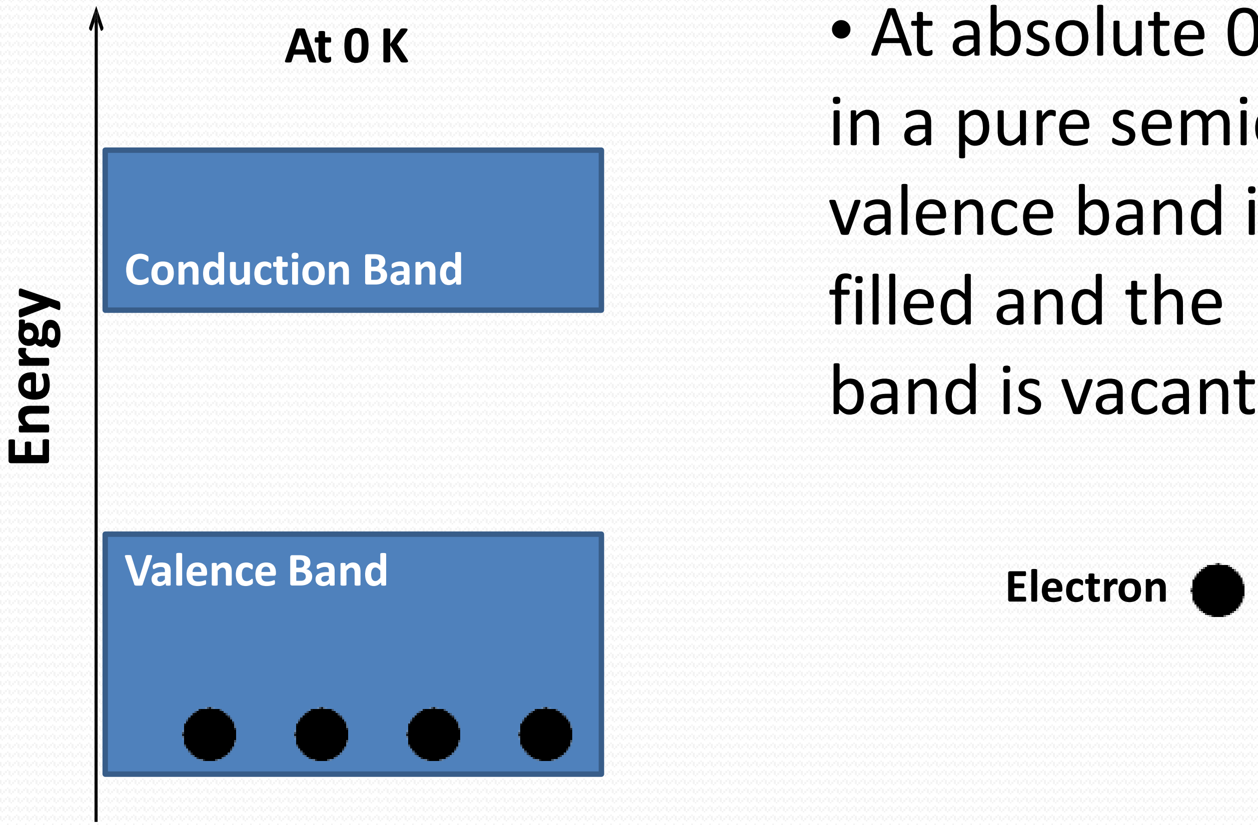


- In the case of semiconductors the forbidden gap is very small.

- At 0K the conduction band is empty and the valence band is completely filled.
- When a small amount of energy is supplied, the electrons can easily jump the forbidden gap.

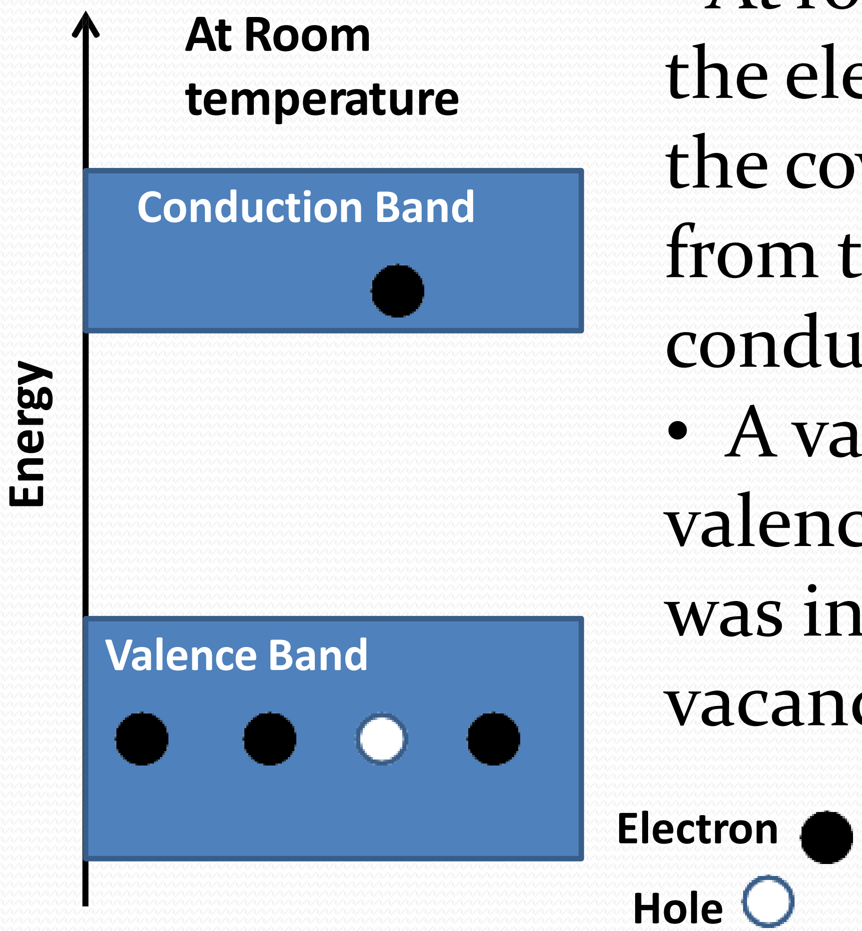
- The conductivity of a semiconductor is of the order of 10^{2}mho m^{-1}

Electrons and holes in semiconductors



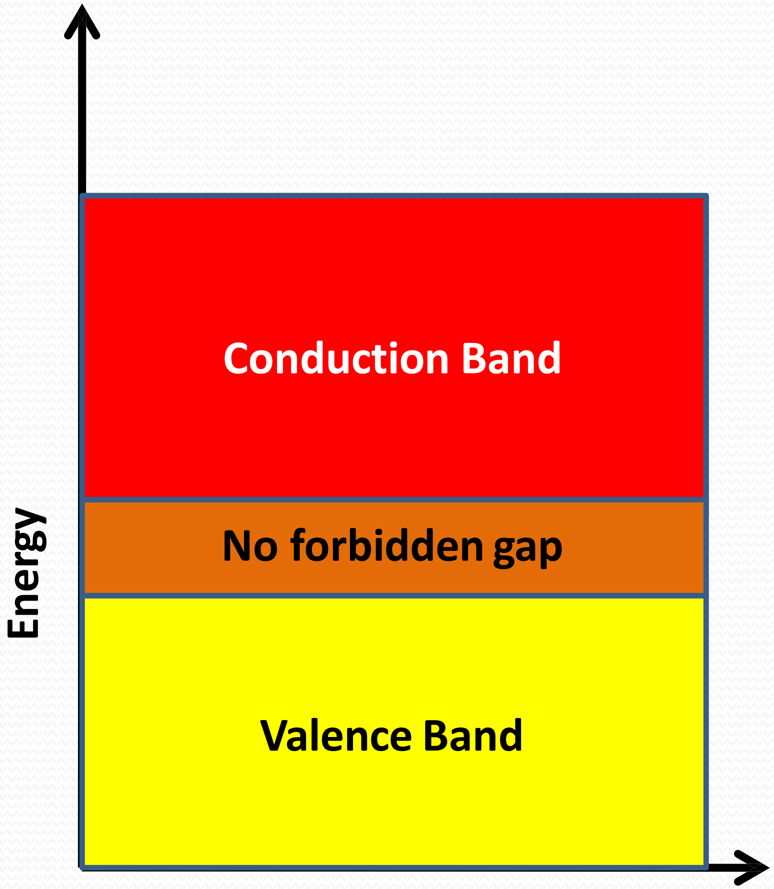
- At absolute 0 temperature, in a pure semiconductor the valence band is completely filled and the conduction band is vacant.

Electrons and holes in semiconductors



- At room temperature some of the electrons get energy to break the covalent bond and jumps from the valence band to conduction band.
- A vacancy is created in the valence band where the electron was initially present and this vacancy is known as a hole.

Conductors



- In conductors there is no forbidden gap.
- The valence band and the conduction band overlap.
- The electrons from valence band freely enter into the conduction band due to overlapping of bands.
- Due to this reason, the current can easily pass through conductors.

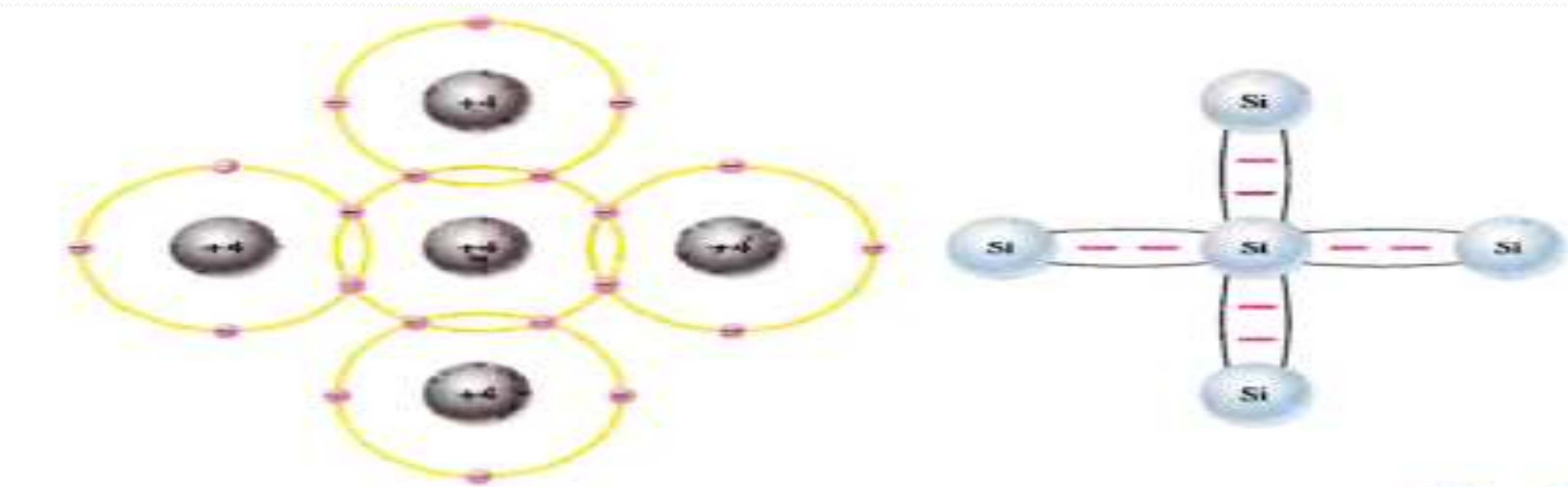
Intrinsic and Extrinsic Semiconductor

- Semiconductors are classified into two types

    a) Intrinsic semiconductor
    b) Extrinsic semiconductor

Intrinsic Semiconductors

A pure semiconductor is known as intrinsic semiconductor. The most common examples of intrinsic semiconducting materials are Silicon and Germanium Each atom of silicon has four valance electrons. Moreover each atom of silicon is surrounded by four atoms.



Extrinsic Semiconductor

Conductivity of intrinsic semiconductors is very low at room temperature. To increase the conductivity, a small amount of external impurity is added to the intrinsic semiconductor. After the addition of an impurity, the semiconductor formed is known as an extrinsic semiconductor.

Doping

The process of deliberately adding a small amount of impurity to a pure semiconductor to increase its conductivity is known as doping.

Dopants:

The impurities added in the process of doping are known as dopants. Two types of impurities or dopants

i) Donor impurities ii) Acceptor impurities

Donor impurities

- The impurities which donate excess of electrons for conduction are called donor impurities.
- Pentavalent elements like antimony (Sb), arsenic(As) or phosphorus (k) are used as donor impurities.

Acceptor impurities

- The impurities which create positive carriers or holes that can accept electrons for conduction are called acceptor impurities.
- Trivalent elements or 3rd group elements like Boron, gallium or indium are generally used as acceptor impurities.

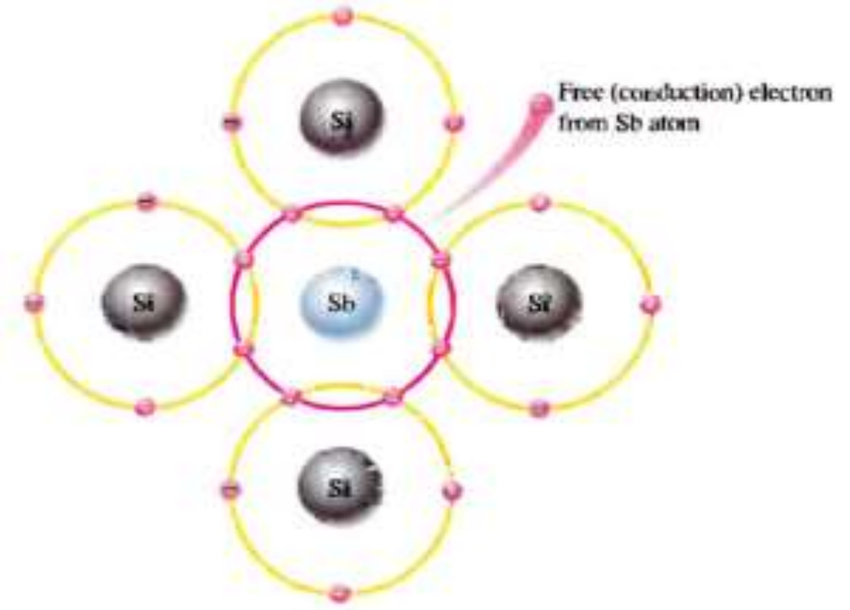
Types of Semiconductors

- Depending upon the nature of impurity added the extrinsic semiconductor can be classified as:

N-type semiconductor
&
P-type semiconductor

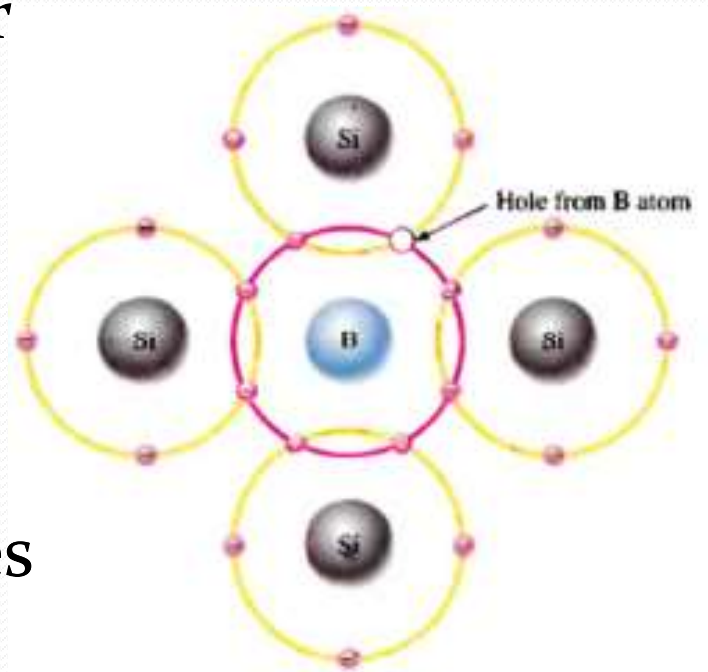
N-type semiconductor

- If we dope a pure semiconductor with a Pentavalent element, an n-type semiconductor is formed.
- Majority charge carrier are electron while minority charge carrier are holes



P-type semiconductor

- If we dope a pure semiconductor with a Trivalent element like Boron, gallium or indium which has 3 valence electrons, a P-type semiconductor is formed.



- Majority charge carriers are holes while minority charge carrier are electrons.