Band gap in solids:

The band gap in solids refers to the energy difference between the valence band (the highest range of electron energies where electrons are normally present) and the conduction band (the range of energies where electrons can move freely within the material, contributing to electrical conduction).

In insulators, the band gap is large, making it difficult for electrons to jump from the valence band to the conduction band, thus preventing electrical conductivity. Semiconductors have a smaller band gap, which can be overcome by thermal excitation or doping, allowing limited electron movement and controlled conductivity. Conductors (like metals) have no significant band gap, allowing free flow of electrons and easy conduction of electricity.

The size of the band gap determines the material's electrical properties, making it a critical concept in electronics, photonics and materials science.

Distinction between metals, semiconductors and insulators with the help of band theory of solids.

The band theory of solids explains the behaviour of electrons in materials, helping to distinguish between metals, semiconductors and insulators based on the arrangement of energy bands, particularly the valence band and the conduction band.

1. Metals:

In metals, the valence band and the conduction band overlap, or the conduction band is partially filled with electrons. Because of this overlap, electrons can move freely within the material even at low energies, allowing metals to conduct electricity easily. There is no band gap or it is effectively zero.

Example: Copper (Cu), Gold (Au)

2. Semiconductors:

Semiconductors have a small band gap between the valence band and conduction band, typically around 0.1 to 2 eV. At absolute zero, the conduction band is empty, but at room temperature or when energy is provided (through heat, light or doping), electrons can jump from the valence band to the conduction band. This allows semiconductors to conduct electricity, but in a controlled and tunable manner depending on external conditions.

Example: Silicon (Si), Germanium (Ge)

3. Insulators:

Insulators have a large band gap, typically greater than 4 eV. The gap between the valence and conduction bands is so large that electrons in the valence band do not have enough energy to move to the conduction band under normal conditions. As a result, insulators do not conduct electricity because there are no free electrons in the conduction band.

Example: Diamond, Glass

Different types of semiconductors:

1. Intrinsic Semiconductors:

It is a pure semiconductor with no impurity added. In an intrinsic semiconductor, the number of electrons in the conduction band is equal to the number of holes in the valence band, both generated by thermal excitation. Conductivity is low at room temperature but increases with temperature. The primary material examples are silicon (Si) and germanium (Ge) in their pure form.

2. n-type Semiconductors:

It is formed by doping an intrinsic semiconductor with a pentavalent element (e.g., phosphorus or arsenic) that has one extra electron. The extra electron becomes a free electron in the conduction band, making electrons the majority charge carriers. The holes are the minority carriers. Conductivity is enhanced due to the availability of extra electrons.

3. p-type Semiconductors:

It is created by doping an intrinsic semiconductor with a trivalent element (e.g., boron or aluminium) that has one fewer electron, creating a hole in the valence band. The holes act as the majority carriers, while electrons are the minority carriers. The introduction of holes allows for conduction as electrons jump to fill these vacancies, creating more holes.