Semiconductor

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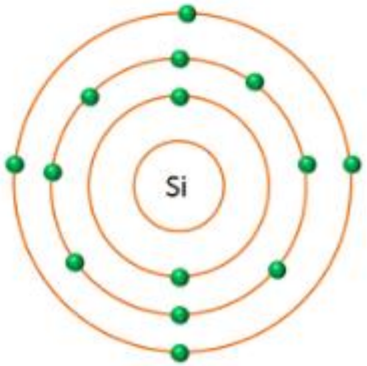
Material Classification

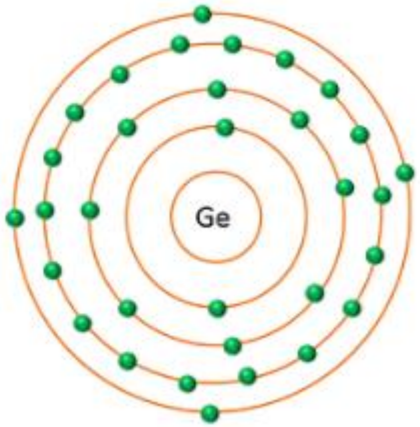
Semiconductor: Depending on conduction of electricity materials are classified as

1. **Conductors:** Resistivity (ρ) $=10^{-6}$ ohm-meter, examples: Copper, Aluminum etc.
2. **Insulators:** Resistivity (ρ) $=10^{13}$ ohm-meter, examples: Rubber, PVC, Paper etc.
3. **Semiconductors:** Resistivity (ρ) between conductors & Insulators, examples: Silicon, Germanium

Semiconductor

- Semiconductors have four electrons in their outer most orbit





Silicon (electrons: 2, 8, 4)   Germanium (electrons: 2,8,16, 4)

- Semiconductors properties (electrical conduction) can be easily manipulated by the addition of impurities, known as doping (electron-hole pair generation)

Energy Level

- When the atoms are place in a crystal form the energy level of each electrons changes due to effect of other closely placed atoms.
- There are 2 types of electrons present in an atom:
  - **Valance electron:** An atom requires 8 electrons in the outer most orbit. So the atom shores electrons with anther atom to attain stability. These shared electrons are known as valance electrons.
  - **Free Electron:** If an electrons receives energy externally such as due to heat, the electrons moves out of the valance band and becomes free. The free electrons has a greater energy than the valance electron.

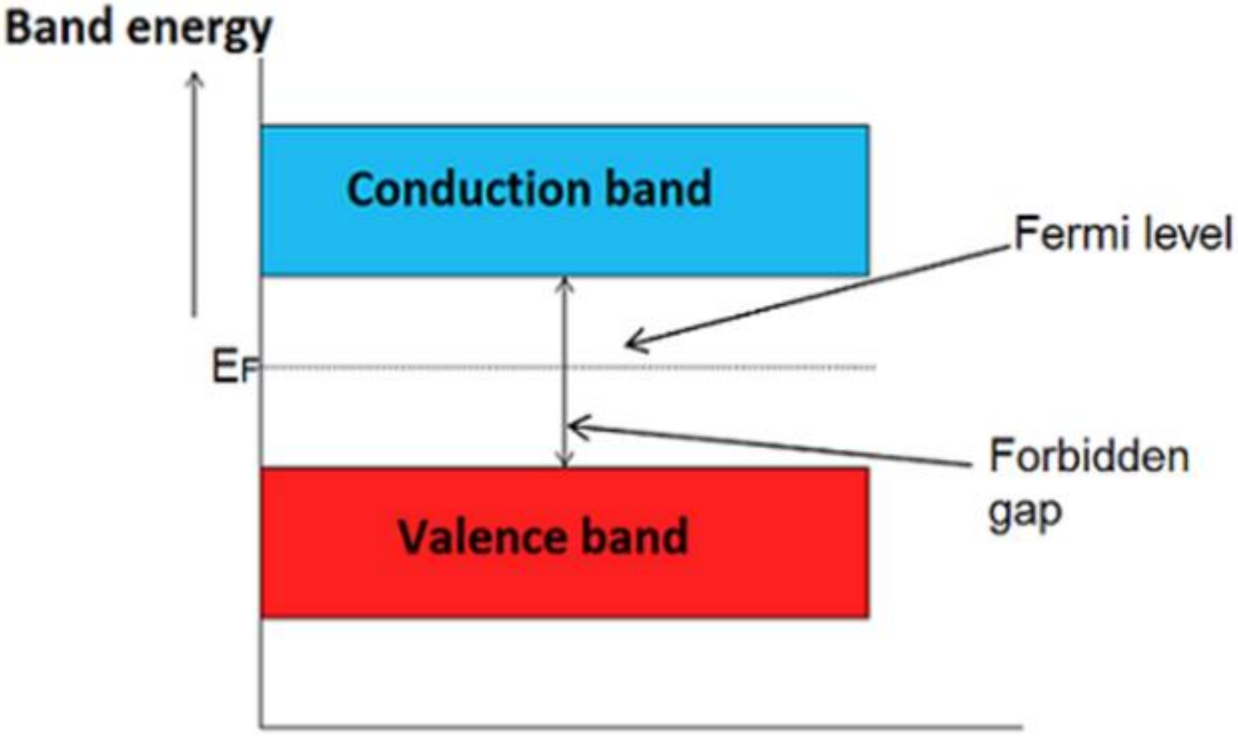
Energy Band

- In crystal formation the energy level (band) of electrons can be categorized into following distinct levels or energy band
  - **Valance Band:** Valence band contains valence electrons. The valence band can be completely filled with electrons or sometimes partially with electrons but it is never empty.
  - **Conduction Band:** Conduction band contains free electrons. It can be empty or partially filled with electrons. As there are free electrons they conduct electricity through the materials.
  - **Forbidden Band or Energy Gap (Eg) and Fermi level:** The forbidden band is completely empty as there are no electrons in it. To move an electron from the valance band to the conduction band an energy equal to the energy gap is required.

Fermi Level

- **Fermi Level:** The probability of occupation of energy levels in valence band and conduction band is called Fermi level.
  - **In intrinsic** or pure semiconductor, the number of holes in valence band is equal to the number of electrons in the conduction band. Hence, the probability of occupation of energy levels in conduction band and valence band are equal. Therefore, the Fermi level for the intrinsic semiconductor lies in the middle of forbidden band.

Fermi Level

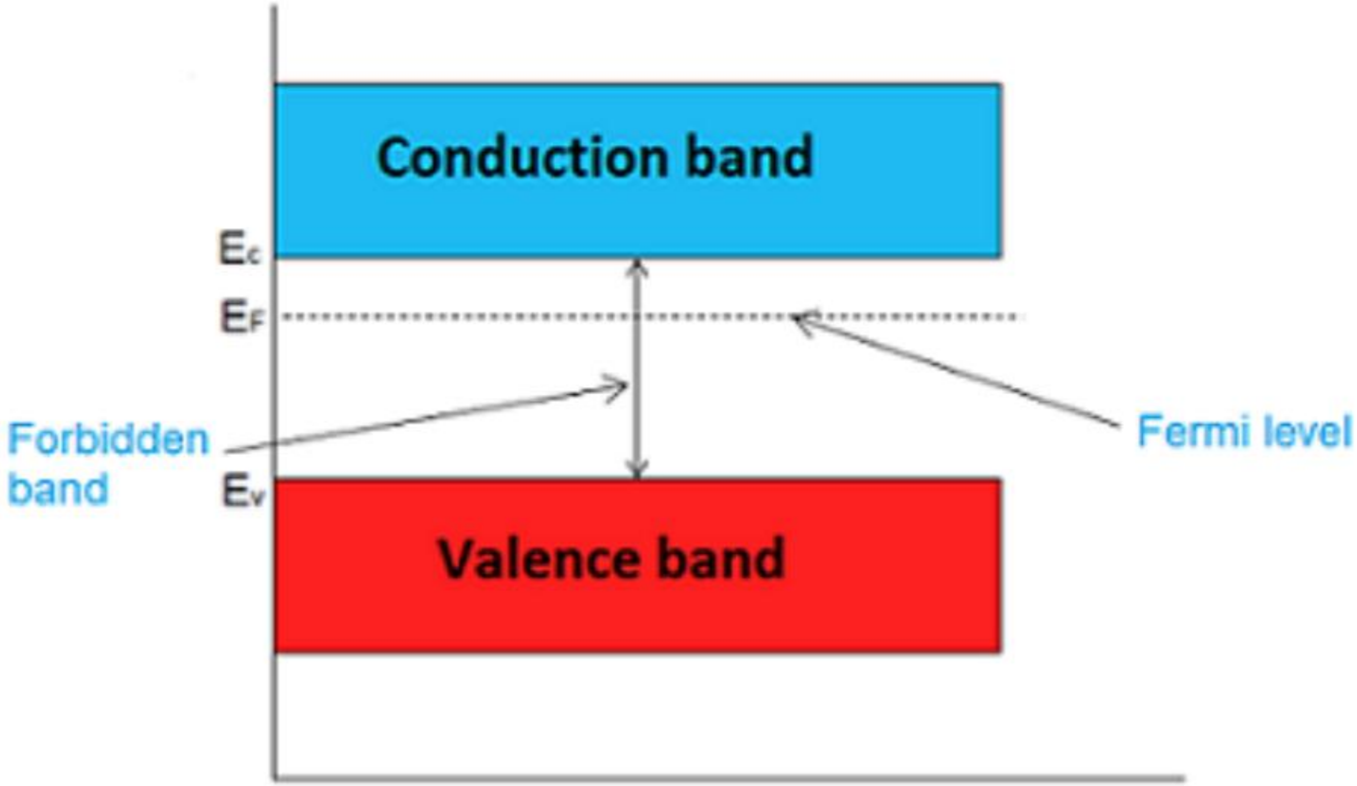


Fermi level for the intrinsic semiconductor

Fermi Level

- **In extrinsic** semiconductor, the number of electrons in the conduction band and the number of holes in the valence band are not equal. Hence, the probability of occupation of energy levels in conduction band and valence band are not equal. Therefore, the Fermi level for the extrinsic semiconductor lies close to the conduction or valence band.

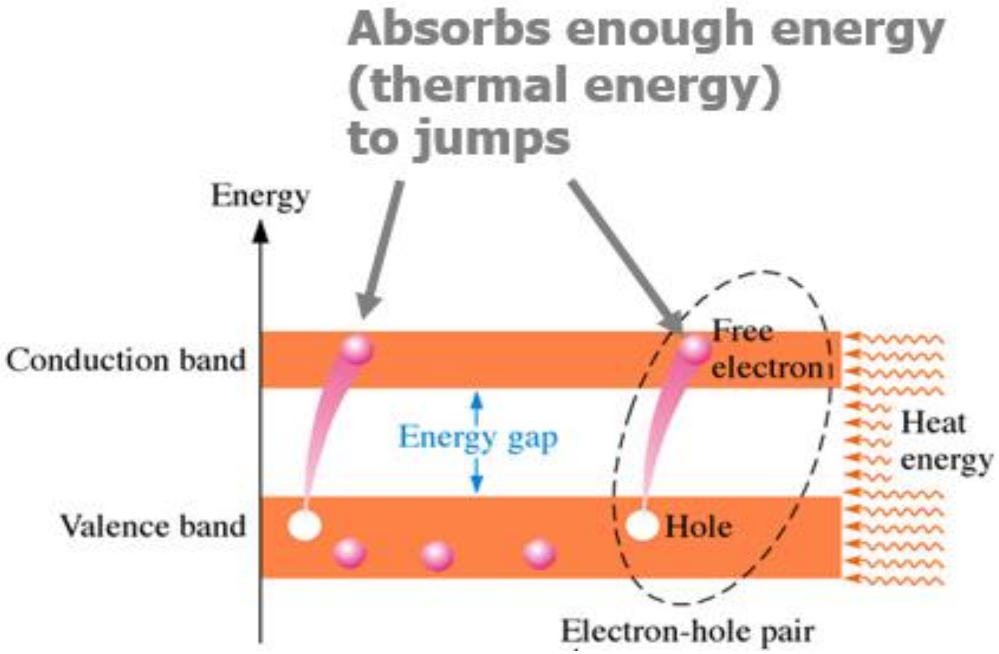
Fermi Level



Fermi level for the extrinsic semiconductor lies close to the conduction or valence band

Conduction in semiconductor

- Electrons and holes pair generation



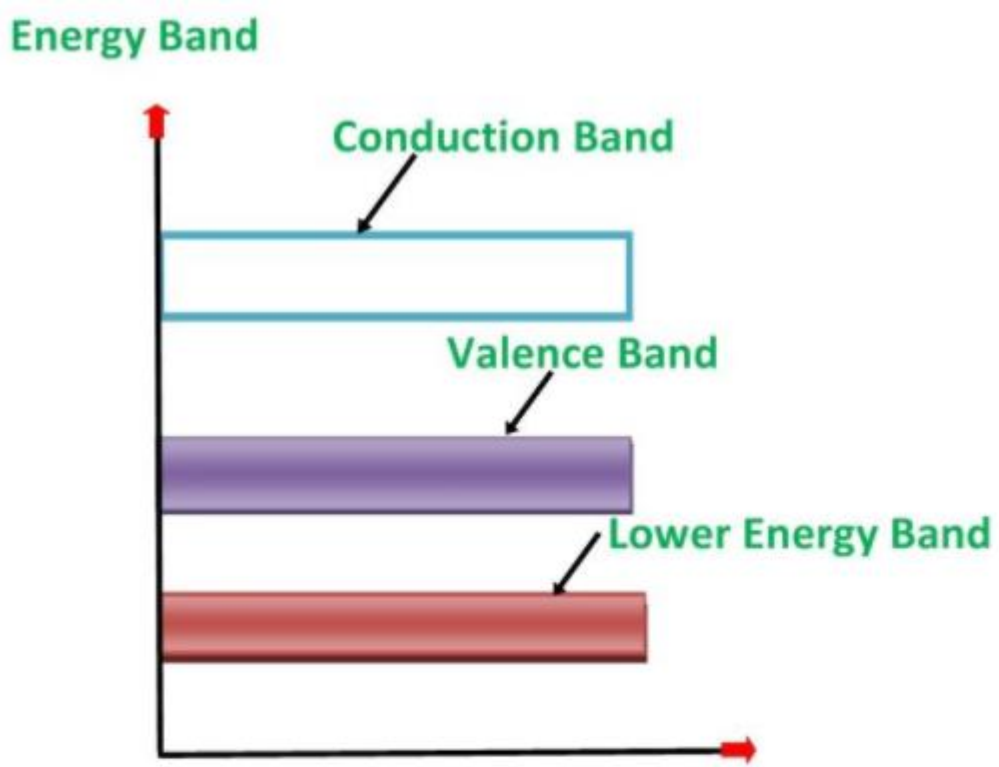
Types of semiconductor

- Intrinsic Semiconductor:
- Extrinsic Semiconductor:

Intrinsic Semiconductor

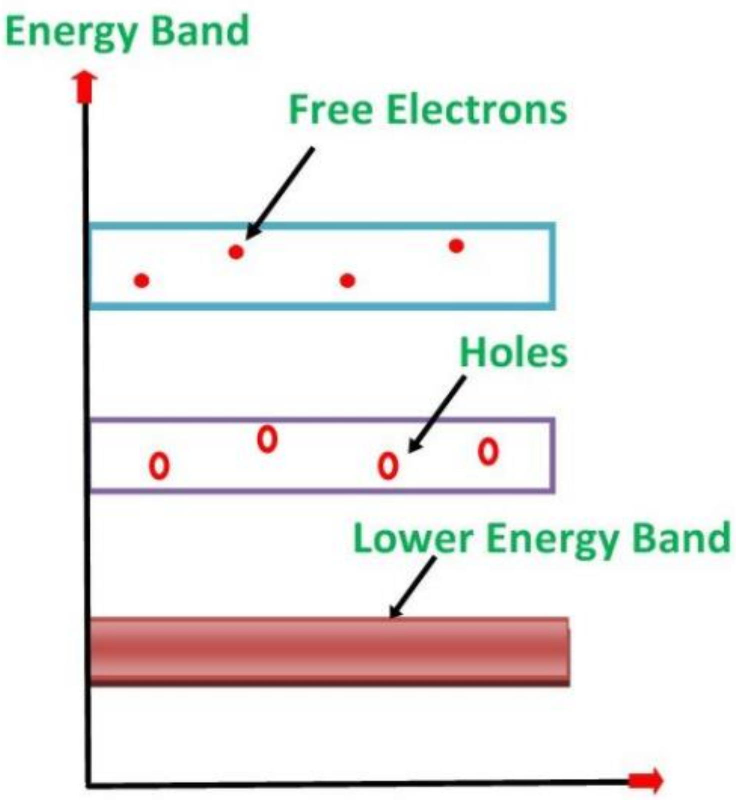
- **Intrinsic Semiconductor:**
  - Pure semiconductors are called intrinsic semiconductors.
  - Intrinsic semiconductor is also called as undoped semiconductor or I-type semiconductor.
  - Conductivity at room temperature (absolute zero temperature i.e $0^{o}K$) = 0

Intrinsic Semiconductor



Energy band at 0^{o}K: Conduction band empty, Valence band completely filled

Intrinsic Semiconductor



Energy band > 0^oK: Conduction free electrons, Valence band holes

Extrinsic Semiconductor

- A semiconductor to which an impurity at controlled rate is added (Doping) to make it conductive is known as an extrinsic Semiconductor.
- Little conduction of electricity even at room temperature (0^0K)
- By doping no of free electrons or holes are increased.
- If a pentavalent impurity, having 5 electrons is added, a large no of free electrons will exist.
- If a trivalent impurity, having 3 electrons is added, a large no of free holes will exist.

Extrinsic Semiconductor

- Depending upon type of impurity added, Extrinsic semiconductor is of two types:
  - **P-Type:** More holes i.e. positively charged materials, trivalent impurity.
  - **N-Type:** More electrons i.e. negatively charged materials, pentavalent impurity.

Thank you

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