

Semiconductor

Lecture Notes: Classification of Materials

1. Introduction

- Materials are classified based on their electrical conductivity.
 - This classification is essential for understanding how materials behave under the influence of electric fields.
-

Classification of Materials

A. Based on Conductivity

1. Conductors:

- High electrical conductivity due to free electrons.
- Examples: Metals like Copper (Cu), Silver (Ag).
- **Conductivity range:**
 - $\sigma \approx 10^2 - 10^8 \text{ S/m}$
 - $\rho \approx 10^{-2} - 10^{-8} \Omega\text{m}$

2. Semiconductors:

- Intermediate conductivity, between conductors and insulators.
- Conductivity varies with temperature or doping.
- Examples: Silicon (Si), Germanium (Ge).
- **Conductivity range:**
 - $\sigma \approx 10^{-6} - 10^5 \text{ S/m}$
 - $\rho \approx 10^{-5} - 10^6 \Omega\text{m}$

3. Insulators:

- Very low conductivity due to the absence of free charge carriers.
 - Examples: Glass, Rubber.
 - **Conductivity range:**
 - $\sigma \approx 10^{-19} - 10^{-11} \text{ S/m}$
 - $\rho \approx 10^{11} - 10^{19} \Omega\text{m}$
-

B. Elemental and Compound Semiconductors

1. Elemental Semiconductors:

- Composed of a single element.
- Examples: Silicon (Si) and Germanium (Ge).

2. Compound Semiconductors:

- Formed by combining two or more elements.

- Categories:
 - **Inorganic compounds:** Examples: Gallium Arsenide (GaAs), Cadmium Sulfide (CdS).
 - **Organic semiconductors:** Examples: Anthracene, doped phthalocyanines.
 - **Polymeric semiconductors:** Examples: Polypyrrole, Polyaniline, Polythiophene.
- **Key Applications:**
 - Si and Ge are extensively used in electronics.
 - Compound semiconductors like GaAs are used in optoelectronics and high-frequency devices.

Energy Band Theory and Band Gap Explanation

A. Energy Bands in Solids:

1. Valence Band:

- Composed of energy levels occupied by valence electrons.
- Electrons are bound to atoms and cannot contribute to conduction.

2. Conduction Band:

- Higher energy band where electrons can move freely and conduct electricity.
- Normally empty in insulators and semiconductors at absolute zero.

3. Energy Gap (Band Gap):

- The energy difference (E_g) between the conduction band and the valence band.
- Determines electrical properties of the material.

B. Classification Based on Band Gap:

1. Conductors:

- No band gap; valence and conduction bands overlap.
- Electrons flow freely, allowing high conductivity.

2. Insulators:

- Large band gap ($E_g > 3 \text{ eV}$).
- Electrons cannot jump from the valence band to the conduction band, leading to negligible conductivity.

3. Semiconductors:

- Moderate band gap ($E_g < 3 \text{ eV}$).
- Electrons can jump to the conduction band with thermal or optical excitation.

Key Characteristics of Materials

Material Type	Band Gap (E_g)	Examples	Behavior
Conductors	$E_g = 0$	Cu, Ag	Free flow of electrons.
Semiconductors	$E_g < 3 \text{ eV}$	Si, Ge, GaAs	Conductivity varies with temperature.
Insulators	$E_g > 3 \text{ eV}$	Glass, Rubber	No significant conduction.

Conclusion

- The classification of materials based on conductivity, elemental composition, and energy band theory provides the foundation for understanding electronic devices.
- Band gap theory explains why different materials exhibit distinct electrical behaviors, crucial for applications in electronics and optoelectronics.

Scan me for a quiz and send the screenshot of the result to 9444929163 in Telegram

