Department of biology

((Biophysics))

1Stage

LEC 5

Conductive, Insulating, and Semiconductors

By

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1. Conductive, Insulating, and Semiconductors

Overview:
Conductive, insulating, and semiconductor materials differ primarily in their ability to conduct electric current, determined by their electron mobility and energy band structure.

a) Conductive Materials

- **Definition:** Materials that allow the easy flow of electric current due to the availability of free electrons.
- **Key Features:**
  - Presence of free electrons forming an "electron cloud."
  - Very low resistivity and high conductivity.
  - Examples: Metals like **silver, copper, and aluminum.**
- **Applications:** Electrical wiring, circuits, and power transmission.
- **Influencing Factors:** Purity and temperature, as higher temperatures often increase resistance in metals.

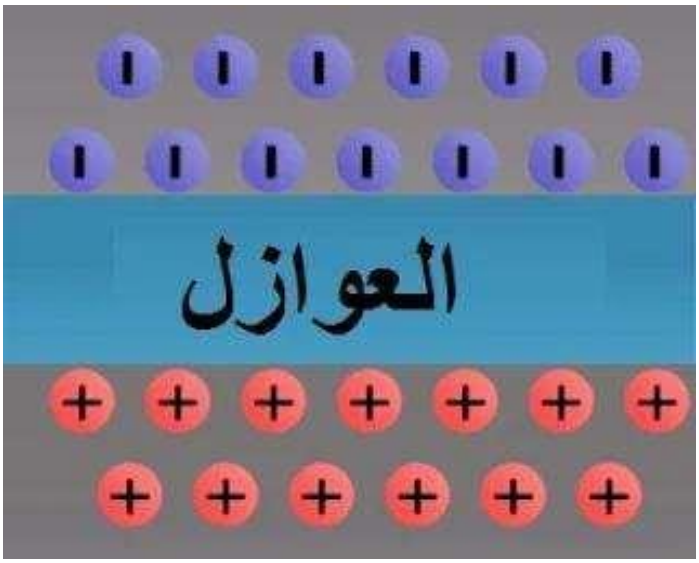
b) Insulating Materials

- **Definition:** Insulating materials are substances that do not readily conduct electricity due to their structure, which restricts the movement of electrons. They have high electrical resistance and are essential for preventing unintended flow of current.

Key Characteristics

1. **High Resistivity:**
   Insulators have very high electrical resistance, making them unsuitable for conducting electricity.
2. **Wide Energy Band Gap:**
   The energy gap between the valence band (where electrons are bound) and the conduction band (where electrons are free to move) is typically **greater than 5 eV.** This gap requires a large amount of energy to allow electron movement, effectively preventing electrical conductivity.
3. **Dielectric Properties:**
   Insulators can store electrical energy when exposed to an electric field, making them useful in capacitors and other applications requiring charge storage.

4. **Thermal Properties:**
   Many insulating materials also have poor thermal conductivity, making them suitable for applications requiring both electrical and thermal insulation.



Examples of Insulating Materials

1. **Natural Insulators:**
   - **Rubber:** Used in electrical wires, gloves, and insulating mats.
   - **Glass:** Commonly used in windows, electrical bulbs, and insulation for high-voltage lines.
   - **Wood (dry):** Acts as an insulator, though its insulating properties diminish with moisture content.
2. **Synthetic Insulators:**
   - **Plastics (e.g., PVC, polyethylene):** Widely used for wire sheathing and protective casings.
   - **Ceramics:** Found in spark plugs, insulators for transformers, and high-voltage lines.
   - **Mica:** Used in capacitors and as a thermal insulator in electronics.
3. **Composite Insulators:**
   - Combine different materials (e.g., polymer-based composites) to enhance specific insulating properties, such as resistance to heat or mechanical stress.

Semiconductors

- **Definition:** Materials with electrical conductivity between conductors and insulators, often influenced by external factors like temperature, doping, or applied voltage.
- **Key Features:**
  - Moderate resistivity and a small band gap (approximately 1-3 eV).
  - At absolute zero, semiconductors behave as insulators, but as the temperature increases, electrons gain energy to move into the conduction band, enhancing conductivity.
  - Examples: **Silicon (Si), germanium (Ge), and gallium arsenide (GaAs).**
- **Applications:** Essential in electronics, including transistors, diodes, solar cells, and integrated circuits.
- **Special Properties:**
  - **Doping:** The addition of impurities (like phosphorus or boron) can modify conductivity, creating **n-type** or **p-type** semiconductors.
  - **Temperature Sensitivity:** Conductivity increases significantly with temperature, unlike metals.

Comparison Between Conductors, Insulators, and Semiconductors

Property	Conductive Materials	Insulating Materials	Semiconductors
Electron Mobility	High (free electrons).	Very low (bound electrons).	Moderate (can be controlled by doping).
Band Gap	None or very small (~0 eV).	Large (>5 eV).	Small (~1-3 eV).
Resistivity	Very low.	Very high.	Moderate, variable.
Examples	Copper, silver, aluminum.	Rubber, glass, plastic.	Silicon, germanium, GaAs.
Applications	Electrical wiring, circuits.	Insulation, safety equipment.	Electronics, solar cells, diodes.

Integration in Electronic Systems

- **Conductors** are used for pathways to carry electric current.
- **Insulators** ensure safety and prevent undesired current flow.
- **Semiconductors** act as controllable elements, enabling complex operations like amplification, switching, and energy conversion.

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Multiple Choice Questions:

1. Which of the following materials is an excellent conductor of electricity?
a) Rubber
b) Glass
c) Copper
d) Plastic

2. What is the typical band gap of an insulating material?
a) 0 eV
b) 1-3 eV
c) Greater than 5 eV
d) Less than 1 eV

3. In semiconductors, what happens to conductivity as temperature increases?
a) Decreases
b) Increases
c) Remains constant
d) Becomes zero

4. Which of the following is an example of a natural insulator?
a) Silicon
b) Rubber
c) Aluminum
d) Gallium arsenide

5. What is the primary mechanism by which semiconductors are made more conductive?
a) Cooling
b) Doping
c) Insulation
d) Melting

6. Which property is most characteristic of conductive materials?
a) High resistivity
b) Moderate band gap

c) Free electrons
d) Dielectric storage

7. What is the main application of insulating materials?
a) To increase current flow
b) To conduct electricity
c) To prevent unintended current flow
d) To amplify signals

8. Which of the following is a widely used semiconductor material?
a) Copper
b) Rubber
c) Silicon
d) Glass

9. Which of these statements about insulators is correct?
a) They have no resistivity.
b) They have high thermal and electrical conductivity.
c) They have a wide band gap and prevent electron movement.
d) They behave as conductors at high temperatures.

10. In an electrical system, what role do semiconductors typically play?
a) They carry current like conductors.
b) They block all current flow.
c) They enable control of current and perform amplification or switching functions.
d) They prevent electrical insulation.