COLLEGE OF ENGINEERING AND TECHNOLOGIES

ALMUSTAQBAL UNIVERSITY

# Electronics

## CTE 207

## Lecture 2

## - Physics of Semiconductor -

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# Introduction



- Electrical resistivity is a fundamental property of a material that measures how strongly it resists electric current.
- A low resistivity indicates a material that readily allows electric current.
- Resistivity is commonly represented by the Greek letter ρ (rho).
- The SI unit of electrical resistivity is the ohmmeter (Ω·m).

# Resistivity

$$\rho = R\frac{A}{l}$$

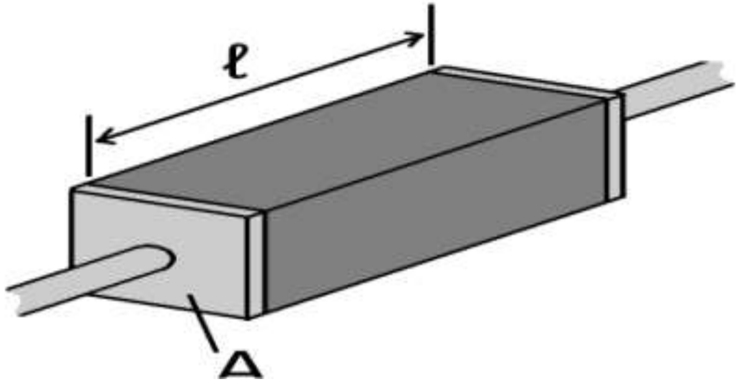


Figure 1: Resistive material with electrical contacts on both ends

Where:

- R is the electrical resistance of a uniform specimen of the material.
- l is the length of the specimen .
- A is the cross-sectional area of the specimen.

# Resistivity



- Both resistance R and resistivity ρ describe how difficult it is to make electrical current flow through a material.

- But unlike resistance, resistivity is an intrinsic property.

- This means that all pure copper wires irrespective of their shape and size, have the same resistivity.

- But a long, thin copper wire has a much larger resistance than a thick, short copper wire.

- Every material has its own characteristic resistivity.

For example, rubber has a far larger resistivity than copper.


Figure 2: Resistivity of rubber and copper

# Conductivity



- Electrical conductivity or specific conductance is the reciprocal of electrical resistivity.
- It represents a material's ability to conduct electric current.
- It is commonly signified by the Greek letter σ (sigma).
- The SI unit of electrical conductivity is siemens per meter (S/m).

$$\sigma = \frac{1}{\rho}$$

Where:

- σ is the electrical conductivity.
- ρ is the electrical resistivity.

## Causes of conductivity

- In Metal: A metal consists of a lattice of atoms, each with an outer shell of electrons that freely dissociate from their parent atoms and travel through the lattice.
- This 'sea' of dissociable electrons allows the metal to conduct electric current.
- When an electrical potential difference (a voltage) is applied across the metal, the resulting electric field causes electrons to drift towards the positive terminal.

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Electrical properties of Insulators, Semiconductors and Conductors

Based on the electrical conductivity all the materials in nature are classified as insulators, semiconductors, and conductors.

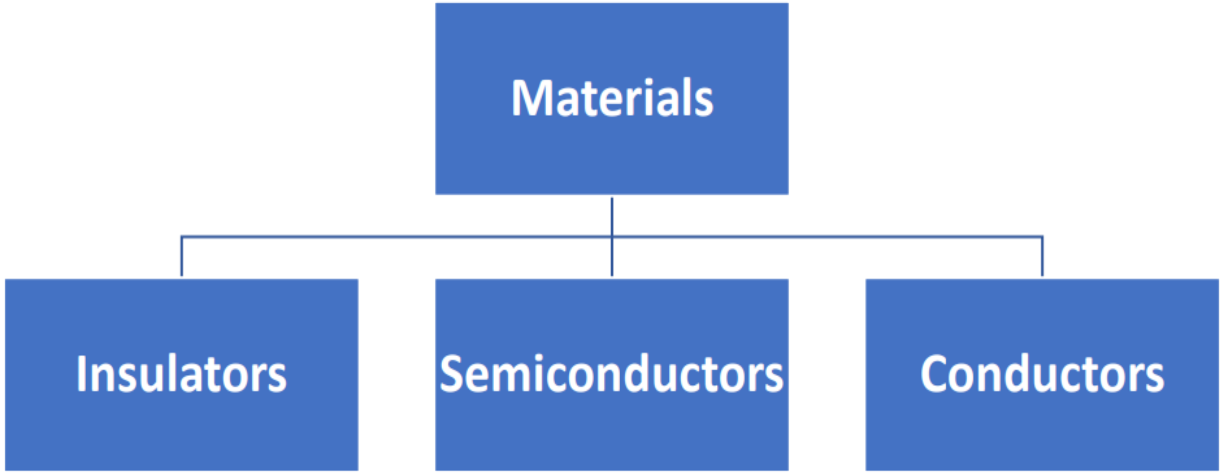


Figure 3: Material classification

# Insulators

- An insulator is a material that offers a very low level (negligible) of conductivity when voltage is applied. Paper, Plastic, Rubber, ….
- Band structure of a material defines the band of energy levels that an electron can occupy.
- Valence band VB: is the range of electron energy where the electron remain bended to the atom and do not contribute to the electric current.
- Conduction bend CB: is the range of electron energies higher than valance band where electrons are free to accelerate under the influence of external voltage source resulting in the flow of charge.

# Material classification

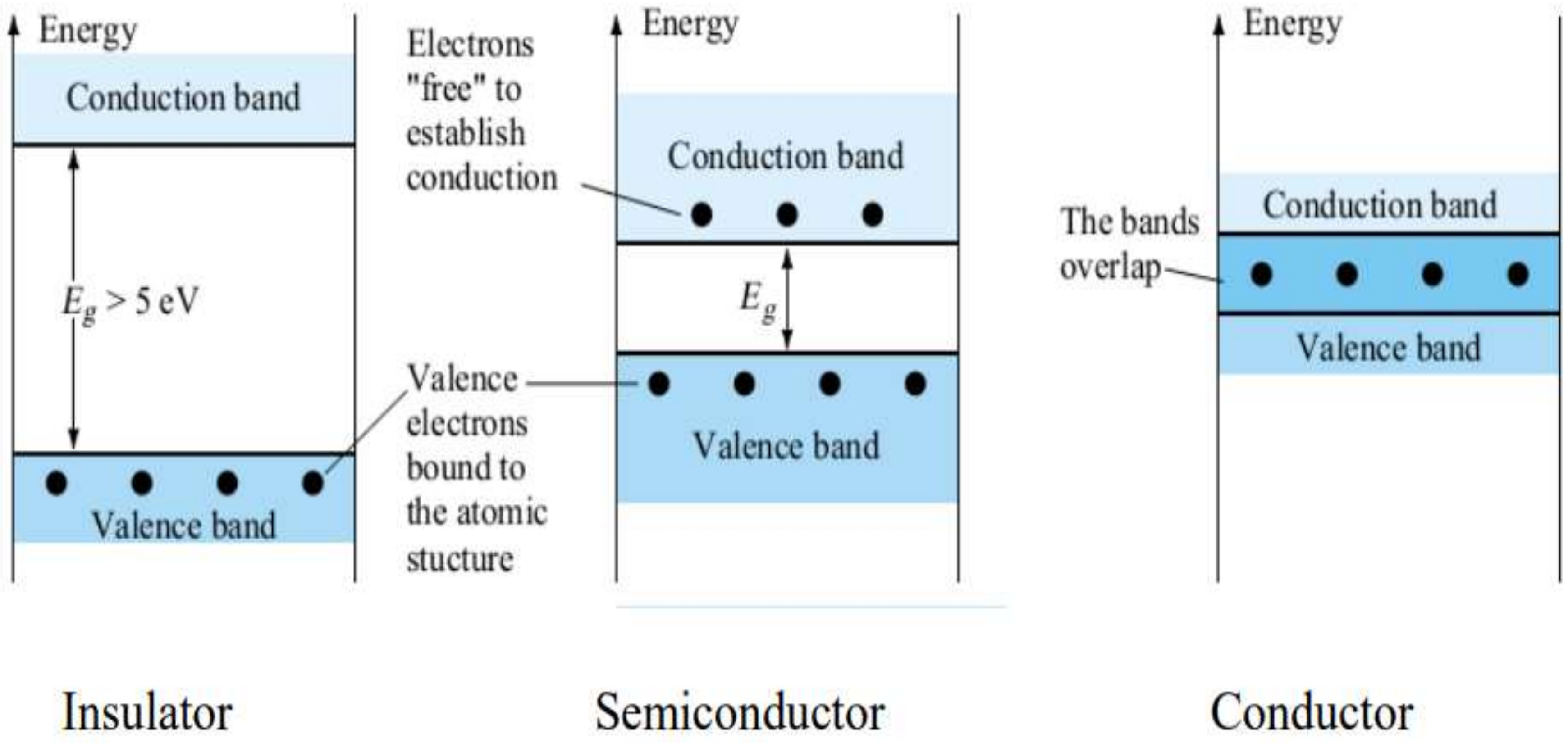


Figure 4: Energy band diagrams insulator, semiconductor and conductor

# Conductors



- A conductor is a material which supports a generous flow of charge when a voltage is applied across its terminals, (it has very high conductivity).

- Eg: Copper, Aluminum, Silver, Gold….

- The Valance and conduction bands overlap and there is no energy gap for the electrons to move from valence band to conduction band.

- This implies that there are free electrons in CB even at absolute zero temperature.

# Semiconductor

- A semiconductor is a material that has its conductivity somewhere between the insulator and conductor.
- Two of the most commonly used are Silicon (Si=14 atomic no.) and germanium (Ge=32 atomic no.).
- Both have 4 valance electrons.

# Energy Levels



- The more distant the electron from the nucleus, the higher the energy state.
- Any electron that has left its parent atom has a higher energy state than any electron in the atomic structure.

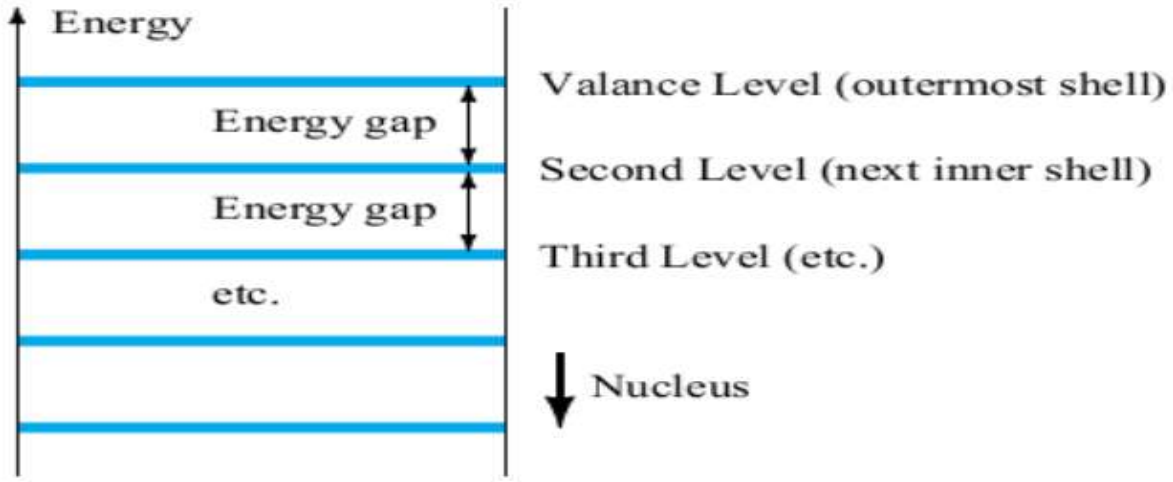


Figure 5: Energy level

# Energy Levels

- Between the discrete energy levels are gaps in which no electrons in the isolated atomic structure can appear.

- Recall that ionization is the mechanism whereby an electron can absorb sufficient energy to break away from the atomic structure and enter the conduction band.

- You will note that the energy associated with each electron is measured in electron volts (eV).

$$1 \text{ eV} = 1.6 \times 10^{-19} \text{ J}$$

- For an insulator, there is a large forbidden band gap of greater than 5Ev.