THREE YEARS DIPLOMA PROGRAM IN ELECTRICAL ENGINEERING 2ND SEM

SEMICONDUCTOR

Introduction to Semiconductors

A semiconductor is a material with conductivity between a conductor (e.g., copper) and an insulator (e.g., glass). Its conductivity can be controlled by temperature, doping, or voltage, making it essential for electronics. Common examples include Silicon (Si), Germanium (Ge), and Gallium Arsenide (GaAs). Semiconductors are the foundation of devices like diodes, transistors, and integrated circuits (ICs), enabling modern technology in computers, communication, and medical equipment.

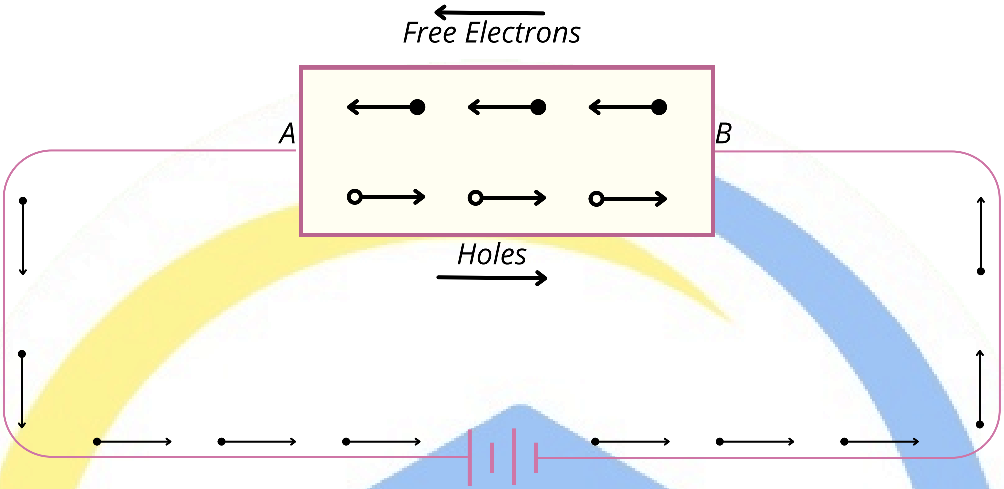
Types of Semiconductors

Semiconductors are categorized into two types **Intrinsic** and **Extrinsic**

1. Intrinsic Semiconductors

Intrinsic semiconductors are pure materials without any added impurities. The most common examples are Silicon (Si) and Germanium (Ge). At absolute zero temperature, they behave as insulators, but as temperature increases, some electrons gain energy and jump from the valence band to the conduction band, increasing conductivity. In intrinsic semiconductors, the number of free electrons is equal to the number of holes (electron deficiencies), ensuring charge balance.
The energy band diagram of an intrinsic semiconductor consists of:

- **Conduction Band:** Where free electrons move, enabling conductivity.
- **Valence Band:** Contains bound electrons that do not contribute to conduction.
- **Energy Gap (Eg):** The minimum energy required for an electron to jump from the valence band to the conduction band.
  - Silicon (Si): 1.1 eV
  - Germanium (Ge): 0.7 eV



2. Extrinsic Semiconductors

Extrinsic semiconductors are those in which impurities (doping) are added to enhance electrical conductivity. The addition of specific elements increases the number of charge carriers (electrons or holes), making them more conductive than intrinsic semiconductors. There are two types of extrinsic semiconductors: **N-Type** and **P-Type.**

(a) N-Type Semiconductor

N-type semiconductors are formed by doping pentavalent elements such as Phosphorus (P), Arsenic (As), or Antimony (Sb) into a pure semiconductor like silicon. These elements have five valence electrons, and when bonded with silicon atoms, one extra electron remains free, increasing conductivity.

- Charge Carriers:
  - Majority: Free electrons (negative charge).
  - Minority: Holes.
- Energy Band Diagram:
  - A donor energy level appears just below the conduction band, requiring minimal energy for electrons to move and conduct electricity.

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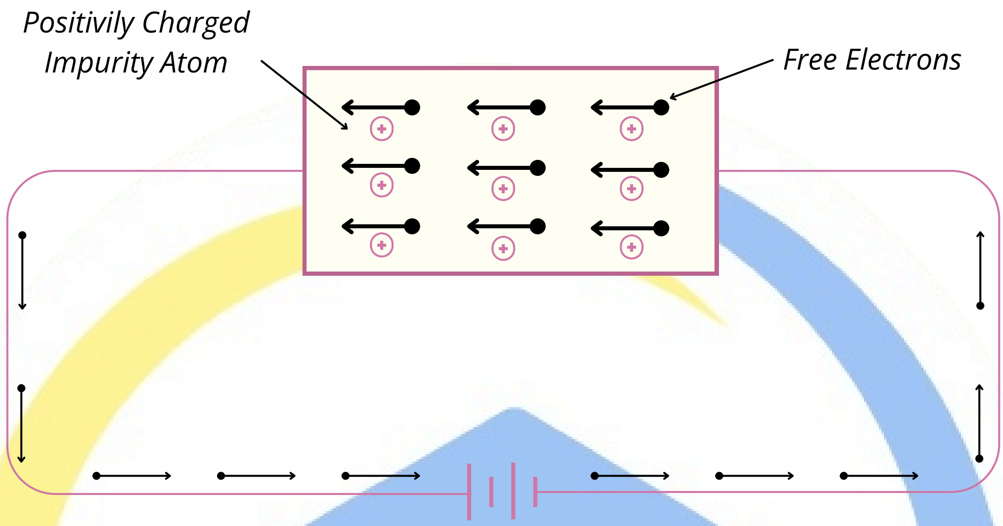
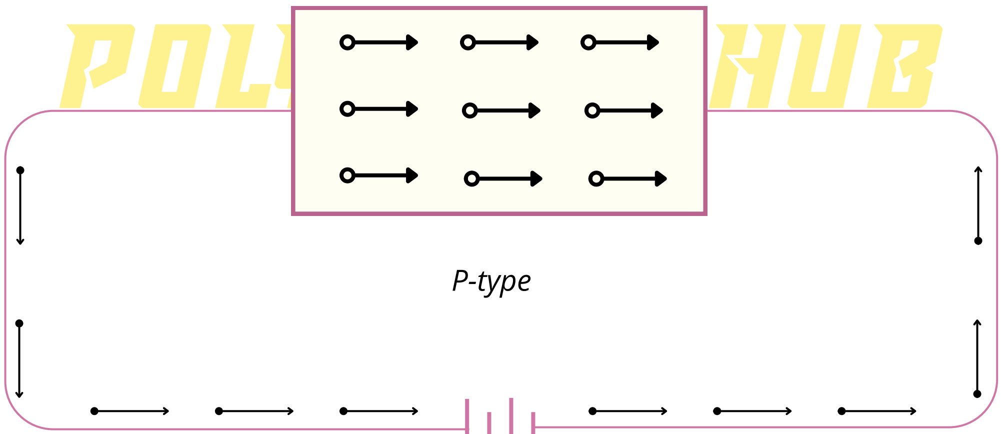


(b) P-Type Semiconductor

P-type semiconductors are created by doping trivalent elements such as Boron (B), Gallium (Ga), or Indium (In) into silicon. These elements have three valence electrons, creating holes (electron deficiencies) in the atomic structure, which act as charge carriers.

- Charge Carriers:
  - Majority: Holes (positive charge).
  - Minority: Free electrons.
- Energy Band Diagram:
  - An acceptor energy level forms slightly above the valence band, making it easier for electrons to jump into holes, thus enabling conduction.



Concept of Doping

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- Charge Carriers:
  - Majority: Holes (positive charge).
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- Energy Band Diagram:
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What is Doping?

Doping is the process of adding controlled impurities to a pure semiconductor (intrinsic semiconductor) to enhance its electrical conductivity. Since pure semiconductors have low conductivity, doping introduces additional charge carriers (free electrons or holes) that improve their performance in electronic applications.
The purpose of doping is to increase the number of charge carriers in a semiconductor. By selecting the right type of impurity, the material can be engineered to have either more free electrons (N-type) or more holes (P-type), making it suitable for different electronic components.

Doping Elements and Their Effects

1. Pentavalent Elements (5 valence electrons): Phosphorus (P), Arsenic (As), Antimony (Sb)
   - These elements donate an extra electron, increasing the number of free electrons.
   - They produce N-type semiconductors (negative charge carriers).

2. Trivalent Elements (3 valence electrons): Boron (B), Gallium (Ga), Indium (In)
   - These elements create holes by forming incomplete bonds.
   - They produce P-type semiconductors (positive charge carriers).

Effect of Temperature on Semiconductors

The electrical conductivity of semiconductors is highly dependent on temperature. Unlike metals, where resistance increases with temperature, semiconductors become more conductive as temperature rises. This is due to changes in the number of charge carriers (electrons and holes).

1. Effect on Intrinsic Semiconductors

- At absolute zero temperature, intrinsic semiconductors behave as insulators because all electrons are bound in the valence band.
- As temperature increases, some electrons gain enough energy to jump from the valence band to the conduction band, creating free electrons and holes.
- This leads to an increase in conductivity, as both free electrons (negative charge) and holes (positive charge) contribute to current flow.

2. Effect on Extrinsic Semiconductors

- At Low Temperatures:
  - Doped semiconductors mainly rely on the impurities (dopants) for charge carriers.
  - Very few electrons are excited thermally, so conductivity remains low.
- At High Temperatures:
  - More electrons gain energy and move to the conduction band, increasing the number of charge carriers.
  - The semiconductor starts behaving like an intrinsic semiconductor, as thermal energy dominates over doping effects.