UNIT-2(SEMI-CONDUCTORS)

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INTRINSIC AND EXTRINSIC SEMI-CONDUCTORS

18. INTRINSIC AND EXTRINSIC SEMICONDUCTORS

Semiconductors are materials whose electrical conductivity lies **between that of conductors and insulators**.

They are classified into two main types:

1. INTRINSIC SEMICONDUCTORS

What is an Intrinsic Semiconductor?

An **intrinsic semiconductor** is a **pure semiconductor** with **no impurities** added.

• The number of electrons = number of holes.

• Conductivity is **entirely due to thermally excited electrons** (from valence band to conduction band).

• At **absolute zero temperature**, it behaves like an insulator.

• As temperature increases, **conductivity increases**.

Example:

• **Pure Silicon (Si)**

• **Pure Germanium (Ge)**

2. EXTRINSIC SEMICONDUCTORS

What is an Extrinsic Semiconductor?

An **extrinsic semiconductor** is a **doped semiconductor**, meaning **small amounts of impurities** are added to increase conductivity.

• Doping introduces **extra charge carriers** (electrons or holes).

• Two types based on the type of impurity added:

- **n-type** (adds electrons)
- **p-type** (adds holes)

a) n-type Semiconductor

• Doped with **pentavalent atoms** (5 valence electrons), like **Phosphorus (P)**, **Arsenic (As)**.

• Extra electrons become **free carriers**.

• **Electrons are majority carriers**, holes are minority.

Example:

• Silicon doped with Phosphorus (Si + P)

b) p-type Semiconductor

• Doped with **trivalent atoms** (3 valence electrons), like **Boron (B)**, **Aluminum (Al)**.

• Creates **holes** (missing electrons) in the crystal.

• **Holes are majority carriers**, electrons are minority.

Example:

• Silicon doped with Boron (Si + B)

19. CONDUCTIVITY IN INTRINSIC SEMICONDUCTORS

What is Conductivity?

Conductivity (σ) is the ability of a material to **allow the flow of electric current**.

In intrinsic semiconductors, conductivity is due to **both electrons and holes** created by thermal excitation.

How Does an Intrinsic Semiconductor Conduct?

1. At **absolute zero**, no electrons are in the conduction band → **no conductivity**.
2. At **higher temperatures**, **thermal energy** excites some electrons from the **valence band to the conduction band**.
3. This leaves behind **holes** in the valence band.
4. Both **electrons and holes** contribute to conduction:
   - **Electrons** move in the conduction band.
   - **Holes** behave like positive charges and move in the valence band.

Conductivity Formula:

$$\sigma = e(n\mu_e + p\mu_h)$$

Where:

• **σ** = conductivity

• **n** = number of electrons in conduction band

• **p** = number of holes in valence band

• **e** = charge of an electron

• **μ_e** = mobility of electrons

• **μ_h** = mobility of holes

For Intrinsic Semiconductors:

Since **$n = p = n_i$** (intrinsic carrier concentration), the formula becomes:

$$\sigma = en_i(\mu_e + \mu_h)$$

Key Points:

• Conductivity **increases with temperature** (more electrons are excited).

• **No external doping** is used — only thermal energy creates charge carriers.

• Conductivity is **much lower** than metals but **higher** than insulators.

Example:

• Pure **Silicon** or **Germanium** at room temperature shows **some conductivity** due to thermally generated **electron-hole pairs**.

20. FORMATION OF P-N JUNCTION DIODE

What is a P-N Junction?

A **p-n junction** is formed when **p-type** and **n-type** semiconductors are joined together.

- **p-type semiconductor** has **excess holes** (positive charge carriers).
- **n-type semiconductor** has **excess electrons** (negative charge carriers).

How is a P-N Junction Formed?

- When the p-type and n-type materials are brought into contact, **electrons from the n-side** diffuse into the p-side.

- Similarly, **holes from the p-side** diffuse into the n-side.
- This diffusion causes electrons and holes to **recombine near the junction**, creating a region depleted of free charge carriers called the **depletion region**.
- The depletion region acts as a **barrier** preventing further flow of electrons and holes.
- An **electric field** is established across the depletion region, forming a **potential barrier**.

21. I-V CHARACTERISTICS OF P-N JUNCTION DIODE

Forward Bias:

- When the **positive terminal of a battery** is connected to the **p-side** and the **negative terminal** to the **n-side**, the diode is **forward biased**.
- The applied voltage **reduces the barrier potential**, allowing charge carriers to cross the junction.
- Current flows through the diode and increases **exponentially** with applied voltage.

Reverse Bias:

- When the **positive terminal** is connected to the **n-side** and the **negative terminal** to the **p-side**, the diode is **reverse biased**.
- The barrier potential **increases**, preventing charge carriers from crossing.
- Only a very small **leakage current** (reverse saturation current) flows.
- No significant current flows even with increasing reverse voltage until **breakdown voltage** is reached.

NOTE:

- The **threshold voltage** (cut-in voltage) for silicon diode is about **0.7 V**.
- In **forward bias**, the diode acts like a **closed switch**.
- In **reverse bias**, the diode acts like an **open switch** until breakdown occurs.

Here's a simple and clear explanation of the **Hall Effect** in your preferred format:

22. HALL EFFECT

What is the Hall Effect?

The Hall Effect is the production of a **voltage difference (Hall voltage)** across an electrical conductor or semiconductor, when a **magnetic field** is applied **perpendicular** to the direction of electric current.

How Does It Happen?

- When current flows through a conductor placed in a magnetic field (perpendicular to current), the **magnetic force** pushes the moving charge carriers (electrons or holes) to one side.
- This causes **charge accumulation** on the sides of the conductor, creating a **transverse voltage** called the **Hall voltage (V_H)**.
- The voltage is **perpendicular** to both the current and the magnetic field.

Hall Voltage Formula:

$$V_H = \frac{IB}{net}$$

Where:

• **I** = current through the conductor

• **B** = magnetic field strength

• **n** = charge carrier density

• **e** = charge of an electron

• **t** = thickness of the conductor (in direction of Hall voltage)

Significance of Hall Effect:

• It helps to **determine the type of charge carriers** (electrons or holes) in a material.

• It measures **carrier concentration (n)**.

• Used to find **magnetic field strength**.

• Widely used in **magnetic sensors** and **Hall effect devices**.

Applications:

- Hall effect sensors for measuring **magnetic fields**.
- Determining **carrier type and density** in semiconductors.
- Used in **speedometers**, **proximity sensors**, and **current sensors**.

23. APPLICATIONS OF HALL EFFECT

The Hall Effect is widely used in many fields because it helps measure magnetic fields and understand material properties.

1. Magnetic Field Measurement

- Hall sensors are used to **measure the strength of magnetic fields** accurately.
- Used in laboratories and industrial instruments.

2. Determining Charge Carrier Type and Concentration

- Helps find whether the charge carriers in a material are **electrons (n-type)** or **holes (p-type)**.
- Measures the **number of charge carriers** in semiconductors.

3. Position and Speed Sensors

- Used in **automobiles** for **speed sensing** (e.g., wheel speed sensors in ABS systems).
- Used in **proximity sensors** to detect the position of moving parts.

4. Current Sensing

- Hall effect sensors measure **current flow** without direct electrical contact (non-invasive).
- Used in power supplies and battery management systems.

5. Magnetic Switches and Encoders

- Used in **magnetic switches** that activate devices when a magnetic field is present.
- Employed in **rotary encoders** to measure angular position and rotation speed.

6. Applications in Electronics and Robotics

- Position sensing for **robotic arms** and moving parts.
- Used in **brushless DC motors** to detect rotor position.

24. SEMICONDUCTOR OPTOELECTRONIC DEVICES

Optoelectronic devices are semiconductor devices that **convert electrical signals into light** or **light into electrical signals**.

1. LIGHT EMITTING DIODE (LED)

What is an LED?

An LED is a **p-n junction diode** that **emits light** when current passes through it.

- When forward biased, electrons and holes recombine in the **depletion region**.
- This recombination releases energy in the form of **light (photons)** — a process called **electroluminescence**.
- The color of light depends on the **semiconductor material and band gap**.

Applications:

- Indicator lights, displays, traffic signals, and lighting.

2. PHOTODIODE

What is a Photodiode?

A photodiode is a **p-n junction diode** designed to **generate current when exposed to light**.

- When light (photons) hits the diode, it creates **electron-hole pairs**.
- These charge carriers create a **photocurrent** proportional to light intensity.
- Usually operated in **reverse bias** for fast response.

Applications:

- Light sensors, optical communication, and safety equipment.

3. SOLAR CELL (PHOTOVOLTAIC CELL)

What is a Solar Cell?

A solar cell is a **p-n junction device** that **converts sunlight directly into electrical energy**.

- When sunlight strikes the solar cell, photons generate **electron-hole pairs**.
- These carriers are separated by the junction's electric field, creating a **voltage and current**.
- Solar cells are connected in arrays to form **solar panels**.

Applications:

- Power generation for homes, satellites, calculators, and remote devices.