UNIT-4(MAGNETIC MATERIAS)

07 August 2025 11:09 PM

CLASSIFICATION OF MAGNEMIC MATERIAL :DIA,PARA,FERRO,ANTI-FERRO, AND FERROMAGNETIC MATERIAL

47. CLASSIFICATION OF MAGNETIC MATERIALS

What are Magnetic Materials?

Magnetic materials are materials that respond to a magnetic field and can be magnetized. Their behavior is based on the **alignment of atomic magnetic moments (spins)**.

Magnetic materials are mainly classified into **five types**:

1. Diamagnetic Materials

- **Definition**: Materials that are **weakly repelled** by a magnetic field.
- **Cause**: All electrons are paired → net magnetic moment is zero.
- **Behavior**: Weak and negative magnetic susceptibility.
- **Examples**: Bismuth, Copper, Gold, Water, Quartz.

Properties:

- Do **not retain magnetism** when the external field is removed.
- Magnetic moment is in the **opposite direction** of the applied field.
- Temperature independent.

2. Paramagnetic Materials

- **Definition**: Materials that are **weakly attracted** by a magnetic field.
- **Cause**: Some unpaired electrons → small net magnetic moment.
- **Behavior**: Small and positive magnetic susceptibility.
- **Examples**: Aluminum, Platinum, Magnesium, Tungsten.

Properties:

- Magnetic moments align slightly with the field.
- Lose magnetism when the field is removed.
- **Susceptibility decreases with increase in temperature** (Curie's law).

3. Ferromagnetic Materials

- **Definition**: Materials that are **strongly attracted** to a magnetic field.
- **Cause**: Large number of unpaired electrons + magnetic domains.
- **Behavior**: Large positive susceptibility.
- **Examples**: Iron, Cobalt, Nickel.

Properties:

- Magnetic domains align strongly with the field.
- **Retain magnetism** even after the field is removed (permanent magnets).
- Show **hysteresis**.
- Curie temperature exists above which ferromagnetism is lost.

4. Antiferromagnetic Materials

- **Definition**: Materials in which **adjacent atomic spins align in opposite directions**, canceling each other out.
- **Cause**: Equal and opposite magnetic moments.
- **Behavior**: Zero or very low net magnetization.
- **Examples**: Manganese oxide (MnO), Nickel oxide (NiO).

Properties:

- Magnetic susceptibility increases with temperature, then decreases after a peak (Néel temperature).
- No net magnetism under normal conditions.

5. Ferrimagnetic Materials

- **Definition**: Similar to antiferromagnetic, but **opposing spins are unequal**, resulting in net magnetization.
- **Cause**: Unequal magnetic moments in opposite directions.
- **Behavior**: Moderate magnetization.
- **Examples**: Ferrites like Fe_3O_4 (magnetite), $ZnFe_2O_4$.

Properties:

- Used in transformers and microwave devices.
- Show hysteresis and retain some magnetism.
- Curie temperature exists.

48. WEISS MOLECULAR FIELD THEORY OF FERROMAGNETISM

What is Weiss Molecular Field Theory?

- Weiss proposed a theory to explain **ferromagnetism** based on the idea of an **internal (molecular) field**.
- This **internal field aligns the magnetic moments (spins)** of atoms even without an external magnetic field.

Key Assumptions of Weiss Theory:

1. **Molecular Field**:
   - Each magnetic atom experiences not only the applied magnetic field (H) but also an **internal field (H_i)** due to interaction with neighboring atoms.
   - This internal field is **proportional to the magnetization (M)**:

$$H_i = \beta M$$

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- where:
  - H_i = internal (molecular) field
  - β = Weiss constant (material-dependent)
  - M = magnetization of the material

2. **Effective Magnetic Field**:
   - The **total effective field** acting on each atom becomes:
   - $$H_{\text{eff}} = H + H_i = H + \beta M$$

3. **Spontaneous Magnetization**:
   - Even when **H = 0**, the internal field can cause a non-zero **spontaneous magnetization** below a certain temperature.

Curie–Weiss Law:

- At high temperatures (above Curie temperature), ferromagnetic materials behave like paramagnets.
- The magnetic susceptibility χ\chi is given by:

$$\chi = \frac{C}{T - T_C}$$

where:

- χ = magnetic susceptibility
- C = Curie constant
- T_C = Curie temperature

Important Concepts:

- **Curie Temperature (Tc)**:

  The temperature above which a ferromagnetic material becomes **paramagnetic**.

- **Below Tc**:

  Magnetic domains align due to the molecular field → **spontaneous magnetization** occurs.

- **Above Tc**:

  Thermal agitation breaks domain alignment → ferromagnetic behavior vanishes.

49. MAGNETIC DOMAINS

What is a Magnetic Domain?

- A **magnetic domain** is a small region within a ferromagnetic material where **all atomic magnetic moments are aligned in the same direction**.
- Even though domains are magnetized, the overall material may appear **non-magnetic** due to **random orientation** of domains.

Behavior:

- **Without magnetic field**: Domains are randomly oriented → no net magnetization.
- **With magnetic field**: Domains aligned in field direction grow → material becomes magnetized.
- **After removing field**: Some domain alignment remains → **residual magnetism**.

50. HYSTERESIS CURVE

What is a Hysteresis Curve?

- A graph that shows how **magnetization (B)** changes as **magnetic field (H)** is cycled.

Key Points on the Curve:

1. **Initial Magnetization Curve**: From unmagnetized state to saturation.
2. **Saturation (Point A)**: Maximum magnetization, all domains aligned.
3. **Retentivity (Point B)**: Residual magnetism when H = 0.
4. **Coercivity (Point C)**: Field required to reduce magnetization to zero.
5. **Negative Saturation (Point D)**: Opposite alignment.
6. **Hysteresis Loop**: Area of loop represents **energy loss per cycle** due to domain movement.

51. SOFT AND HARD MAGNETIC MATERIALS

Soft Magnetic Materials:

- **Easily magnetized and demagnetized**.
- **Low coercivity**, **low hysteresis loss**, **high permeability**.
- Used in **transformer cores, electric motors**.
- **Examples**: Soft iron, silicon steel.

Hard Magnetic Materials:

- **Difficult to magnetize/demagnetize**.
- **High coercivity**, **high retentivity**, **large hysteresis loop**.
- Used for **permanent magnets**.
- **Examples**: Steel, Alnico, Ferrites (some types).

52. FERRITES

What are Ferrites?

- Ferrites are **ceramic-like magnetic materials** made from **iron oxide (Fe_2O_3)** mixed with other metals like Zn, Mn, Ni.
- They are **ferrimagnetic** and have **high electrical resistivity**.

Types of Ferrites:

- **Soft ferrites**: Low coercivity, used in cores.
- **Hard ferrites**: High coercivity, used in magnets.

53. APPLICATIONS OF FERRITES

- **Transformer cores** (reduce eddy current losses)
- **Inductors and chokes** in electronic circuits
- **High-frequency devices** like antennas and filters
- **Memory devices** in computers (magnetic cores)
- **Permanent magnets** (in speakers, motors)
- **Microwave components** (isolators, circulators)