Discipline: Actual problems of chemistry of polymer composites

Lecture 14.

Theme: Magnetic Polymer Composites. Methods of Their Obtaining

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Objective:

To understand the **principles, types, and methods of producing magnetic polymer composites**, and to analyze how magnetic fillers influence the properties and applications of polymer-based materials.

Key Questions:

1. What are magnetic polymer composites, and what are their main components?
2. What types of magnetic fillers are used in polymer composites?
3. What methods are used to fabricate magnetic polymer composites?
4. How do magnetic fillers affect the mechanical and magnetic properties of composites?
5. What are the practical applications of magnetic polymer composites?

Lecture Content:

- **Introduction to Magnetic Polymer Composites:**
  - Composites that combine a **polymer matrix with magnetic fillers** to provide **magnetic functionality**.
  - The polymer matrix can be **thermoplastic, thermoset, or elastomeric**, serving as a binder for the magnetic particles.
  - Applications: sensors, actuators, electromagnetic shielding, data storage, and biomedical devices.
- **Types of Magnetic Fillers:**
  1. **Ferrites:** barium ferrite ($BaFe_{12}O_{19}$), strontium ferrite, and magnetite (Fe_3O_4).
  2. **Metallic magnetic powders:** iron, cobalt, nickel, and their alloys.
  3. **Nanomagnetic particles:** superparamagnetic iron oxide nanoparticles (SPIONs).
  4. **Soft and hard magnetic materials:**
     - Soft: low coercivity, used in transformers and sensors.
     - Hard: high coercivity, used in permanent magnets.
- **Methods of Obtaining Magnetic Polymer Composites:**

1. **Melt Blending:**
    - Magnetic fillers are dispersed in a molten polymer using **extrusion or internal mixers**.
    - Suitable for thermoplastics.
    - Requires good **particle dispersion** and sometimes surface modification for adhesion.
2. **Solution Casting / Solvent Processing:**
    - Magnetic particles are dispersed in a polymer solution, then cast and solvent evaporated.
    - Allows **better dispersion at the nanoscale**, suitable for thin films.
3. **In-Situ Polymerization:**
    - Magnetic particles are added during **monomer polymerization**.
    - Ensures **strong interfacial bonding** between filler and matrix.
4. **Electrospinning and Fiber Formation:**
    - Magnetic nanoparticles embedded in polymer fibers during electrospinning.
    - Used for **functional textiles, sensors, and biomedical scaffolds**.
5. **Hot Pressing and Compression Molding:**
    - Powdered magnetic fillers mixed with polymer powders and pressed under heat.
    - Suitable for **high filler loadings** and structural parts.

- **Factors Influencing Properties:**
    - **Filler type, size, and shape:** affects coercivity, saturation magnetization, and mechanical strength.
    - **Filler content:** higher content increases magnetic response but may reduce flexibility.
    - **Dispersion and interfacial adhesion:** key for mechanical integrity and uniform magnetic properties.
- **Applications:**
    - **Electronics:** inductors, transformers, and EMI shielding.
    - **Medical:** targeted drug delivery, MRI contrast agents, and hyperthermia therapy.
    - **Automotive:** sensors and actuators.
    - **Smart materials:** magnetic actuators, self-healing composites, and soft robotics.

Key Short Theses:

1. Magnetic polymer composites consist of a **polymer matrix and magnetic fillers** to provide functional properties.

2. Magnetic fillers include **ferrites, metallic powders, and magnetic nanoparticles**.
3. Fabrication methods: **melt blending, solution casting, in-situ polymerization, electrospinning, and compression molding**.
4. Particle **size, shape, and dispersion** directly influence magnetic and mechanical properties.
5. Proper interfacial bonding ensures **durable composites with uniform magnetic behavior**.
6. Applications span **electronics, medicine, automotive, and smart materials**.
7. Design requires balancing **magnetic performance with mechanical flexibility and processability**.

Control Questions:

1. Define magnetic polymer composites and explain their main components.
2. List the main types of magnetic fillers used in polymer composites.
3. Describe at least three methods for producing magnetic polymer composites.
4. How do particle size and dispersion affect the properties of these composites?
5. What are the advantages of in-situ polymerization for magnetic composites?
6. Give examples of applications in medicine and electronics.
7. What factors must be balanced when designing magnetic polymer composites?

Recommended references

Main literature:

1. Introduction to Polymer Science and Chemistry: A Problem-Solving Approach, Second Edition 2nd Edition / by Manas Chanda, CRC Press; 2nd edition (January 11, 2013)
2. Polymer Chemistry 2nd Edition / by Paul C. Hiemenz, Timothy P. Lodge, CRC Press; 2nd edition (February 15, 2007)
3. Semchikov Yu.D. High-molecular compounds: Textbook for universities. Moscow: Academy, 2003, 368.
4. S. Thomas, K. Joseph, S.K. Malhotra, K. Goda, M.S. Sreekala. Polymer composites. – Wiley-VCH, 2012. – 829 p.
5. Irmukhametova G.S. Fundamentals of polymer composite materials technology: textbook for universities; Al-Farabi Kazakh National University. - Almaty: Kazakh University, 2016. - 175 p.

Additional literature:

1. Polymer composite materials (part 1): a tutorial / L.I. Bondaletova, V.G. Bondaletov. - Tomsk: Publishing house of Tomsk Polytechnic University, 2013. - 118 p.
2. Polymer composite materials: structure, properties, technology. Edited by Berlin A.A. - St. Petersburg, Publishing house "Profession", 2008. - 560 p.
3. Polymer composite materials: structure, properties, technology: a tutorial / M.L. Kerber et al.; under the general editorship of A.A. Berlin. - St. Petersburg: Profession, 2009.- 556, [4] p.
4. Bataev, A.A. Composite materials. Structure, production, application: a tutorial. manual / A. A. Bataev, V. A. Bataev. - M.: Logos, 2006. - 397, [3] p. - (New University Library).