Discipline: Actual problems of chemistry of polymer composites

Lecture 12.

Theme: Manufacturing of Dispersed Reinforcements for Polymer Composites

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Objective:

To understand the **methods for producing dispersed (particulate) reinforcements**, their characteristics, and how they influence the **properties of polymer composites**.

Key Questions:

1. What are dispersed reinforcements, and why are they used in polymer composites?
2. What are the main types of dispersed fillers?
3. How are different dispersed reinforcements manufactured?
4. How do particle size, shape, and distribution affect composite properties?
5. What methods are used to incorporate dispersed reinforcements into polymer matrices?

Lecture Content:

- **Overview of Dispersed Reinforcements:**
  - Dispersed reinforcements are **particles, platelets, or powders** added to polymer matrices to enhance **mechanical, thermal, or functional properties**.
  - They provide **reinforcement, dimensional stability, wear resistance, and cost reduction**.
  - Commonly used in **thermoplastics, thermosets, and elastomers**.
- **Classification of Dispersed Reinforcements:**
  1. **Mineral fillers:** silica, talc, mica, calcium carbonate, kaolin.
  2. **Metallic powders:** aluminum, copper, iron.
  3. **Ceramic particles:** alumina, zirconia, silicon carbide.
  4. **Synthetic fillers:** carbon black, graphene, nanoclays, fumed silica.
- **Manufacturing Methods for Dispersed Reinforcements:**
  1. **Mechanical Milling and Grinding:**
     - Crushing, ball milling, or jet milling to reduce particle size.
     - Used for minerals, metals, and ceramics.

2. **Precipitation and Chemical Synthesis:**
    - Controlled chemical reactions to produce **uniform particle size and shape**.
    - Examples: precipitated silica, titanium dioxide.
3. **Spray Drying and Agglomeration:**
    - Produces **powdered fillers** with controlled particle size and morphology.
4. **Flame and Pyrolytic Methods:**
    - Used for **carbon black, fumed silica, and other nanoscale particles**.
    - High surface area and fine particle size enhance reinforcement.
5. **Nanotechnology Methods:**
    - Sol-gel synthesis, hydrothermal methods, or exfoliation for **nanoclays, graphene, and other nanoscale fillers**.

- **Influence of Particle Characteristics on Composites:**
    - **Size:** smaller particles improve surface area and interaction with polymer; nanoscale particles can improve mechanical and barrier properties.
    - **Shape:** spherical, plate-like, or fibrous shapes influence stress transfer and rheology.
    - **Distribution:** uniform dispersion avoids agglomeration and ensures consistent properties.
- **Incorporation Methods into Polymers:**
    - **Melt blending:** mixing fillers into molten polymer.
    - **Solution blending:** dispersing fillers in polymer solution, then solvent removal.
    - **In-situ polymerization:** fillers are dispersed during polymer formation.
- **Applications:**
    - Mineral fillers for **dimensional stability and cost reduction** in thermoplastics.
    - Carbon black and graphene for **conductive composites**.
    - Ceramic particles for **wear-resistant and high-temperature composites**.
    - Nanoparticles for **barrier films, coatings, and high-performance composites**.

Key Short Theses:

1. Dispersed reinforcements include **particles, platelets, and powders** to enhance composite properties.
2. Types: mineral, metallic, ceramic, synthetic, and nanoscale fillers.

3. Manufacturing methods: **mechanical milling, chemical precipitation, spray drying, pyrolytic methods, and nanotechnology approaches**.
4. Particle **size, shape, and distribution** critically influence mechanical, thermal, and barrier properties of composites.
5. Incorporation into polymers is achieved via **melt blending, solution blending, or in-situ polymerization**.
6. Proper dispersion prevents **agglomeration** and ensures uniform performance.
7. Dispersed reinforcements are widely used for **structural, functional, and high-performance applications**.

Control Questions:

1. Define dispersed reinforcements and their role in polymer composites.
2. What are the main types of dispersed fillers used in composites?
3. Describe at least three methods for manufacturing dispersed reinforcements.
4. How do particle size and shape affect the properties of polymer composites?
5. Name three methods for incorporating dispersed reinforcements into polymer matrices.
6. What problems can arise if dispersed particles are not properly distributed?
7. Give examples of applications for mineral, carbon, and ceramic dispersed fillers.

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).