Discipline: Actual problems of chemistry of polymer composites

Lecture 3.

Theme: Main Characteristics of Dispersed Reinforcements

Objective:

To understand the **key features and characteristics of dispersed reinforcements** in polymer composites, including their **size, shape, distribution, and surface properties**, and how these factors influence the composite's performance.

Key Questions:

1. What are dispersed reinforcements in polymer composites?
2. What are the main characteristics of dispersed reinforcements?
3. How do particle size, shape, and aspect ratio affect composite properties?
4. What role does surface chemistry and surface modification play?
5. How does the distribution of reinforcements affect mechanical, thermal, and functional properties?

Lecture Content:

- **Definition:**
  - Dispersed reinforcements are small particles, fibers, or platelets distributed throughout the polymer matrix to improve mechanical, thermal, or functional properties.
  - Unlike continuous fibers, dispersed reinforcements are typically **short, small, or irregularly shaped**.
- **Main Characteristics of Dispersed Reinforcements:**
  1. **Size and Size Distribution:**
     - Particle/fiber diameter, length, and aspect ratio influence **mechanical reinforcement** and processing.
     - Smaller particles can improve stiffness and barrier properties but may increase viscosity.
  2. **Shape and Aspect Ratio:**
     - Spherical, irregular, flake, or needle-like shapes affect stress transfer and anisotropy.
     - High aspect ratio fibers or platelets provide better load transfer than low aspect ratio particles.

3. **Surface Area and Surface Chemistry:**
   - High surface area improves **matrix-reinforcement adhesion**, increasing strength and toughness.
   - Surface modifications (e.g., silane coupling agents) enhance interfacial bonding.
4. **Distribution and Dispersion:**
   - Uniform dispersion prevents agglomeration and stress concentrations.
   - Clustering of particles reduces effectiveness and may cause weak points.
5. **Mechanical, Thermal, and Functional Influence:**
   - Reinforcement characteristics affect **tensile strength, modulus, toughness, thermal expansion, conductivity, and barrier properties**.
6. **Processing Considerations:**
   - Size, shape, and surface properties influence **rheology, mixing, and molding** of composites.

- **Examples:**
  - Carbon black in rubbers improves tensile strength and wear resistance.
  - Silica nanoparticles enhance thermal stability and stiffness.
  - Short glass fibers increase mechanical strength in thermoplastics.

Key Short Theses:

1. Dispersed reinforcements are **short, small, or irregularly shaped** additives distributed in a polymer matrix to improve properties.
2. **Size and size distribution** influence stiffness, viscosity, and mechanical performance.
3. **Shape and aspect ratio** affect stress transfer efficiency and anisotropy.
4. **Surface area and chemistry** determine interfacial adhesion and load transfer.
5. **Uniform distribution** is critical to avoid weak points and agglomeration.
6. Reinforcement characteristics directly affect **mechanical, thermal, and functional behavior** of the composite.
7. Surface treatments and modifications enhance **compatibility with the matrix** and overall composite performance.

Control Questions:

1. What are dispersed reinforcements and how do they differ from continuous reinforcements?
2. How does particle size and distribution affect composite properties?

3. What is the influence of reinforcement shape and aspect ratio on mechanical behavior?
4. Why is surface chemistry important for dispersed reinforcements?
5. How does uniform dispersion of reinforcements improve composite performance?
6. Give examples of dispersed reinforcements and their applications.

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).