

Discipline: Actual problems of chemistry of polymer composites

Lecture 4.

Theme: Main Types and Characteristics of Fiber Reinforcements

Objective:

To understand the **different types of fiber reinforcements** used in polymer composites, their **key characteristics**, and how these fibers influence the mechanical, thermal, and functional properties of composites.

Key Questions:

1. What are fiber reinforcements in polymer composites?
 2. What are the main types of fiber reinforcements?
 3. What are the key characteristics of fibers affecting composite performance?
 4. How does fiber type, length, and orientation influence mechanical and thermal properties?
 5. What applications are typical for different fiber types?
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Lecture Content:

- **Definition:**
 - Fiber reinforcements are elongated materials (continuous or short) embedded in a polymer matrix to improve **strength, stiffness, and toughness**.
 - Fibers are one of the most effective reinforcements due to their **high aspect ratio and directional load-carrying capacity**.
- **Main Types of Fiber Reinforcements:**
 1. **Glass Fibers:**
 - Most widely used, good tensile strength, moderate cost.
 - Types: E-glass (electrical applications), S-glass (high-strength applications).
 2. **Carbon Fibers:**
 - High stiffness and strength, low density, good thermal and chemical resistance.
 - Used in aerospace, automotive, and sports equipment.
 3. **Aramid Fibers (Kevlar):**
 - High toughness, impact and abrasion resistance, lightweight.

- Applications: ballistic protection, ropes, composites with high energy absorption.
- 4. **Natural Fibers:**
 - Hemp, flax, jute, sisal; biodegradable, low cost, moderate strength.
 - Applications: automotive interiors, environmentally friendly composites.
- 5. **Other Specialty Fibers:**
 - Boron, basalt, ceramic fibers for high-performance or extreme conditions.
- **Key Characteristics of Fiber Reinforcements:**
 - **Length:** Continuous fibers provide maximum strength along the fiber axis; short fibers provide more isotropic reinforcement.
 - **Diameter:** Smaller diameter increases surface area, improving matrix bonding.
 - **Aspect Ratio (Length/Diameter):** Higher aspect ratio improves load transfer and stiffness.
 - **Mechanical Properties:** Tensile strength, modulus, elongation, toughness.
 - **Thermal Properties:** Heat resistance, coefficient of thermal expansion.
 - **Chemical Resistance:** Stability in corrosive or harsh environments.
 - **Orientation and Distribution:** Aligned fibers maximize directional strength; random orientation provides more uniform properties.
- **Applications:**
 - Aerospace: carbon and glass fiber composites for high-strength, lightweight structures.
 - Automotive: glass and natural fibers for panels, interiors, and structural components.
 - Sporting goods: carbon and aramid fibers for bikes, rackets, and helmets.
 - Industrial: boron, basalt, or ceramic fibers for high-temperature or wear-resistant components.

Key Short Theses:

1. Fiber reinforcements are **elongated materials** that significantly enhance strength, stiffness, and toughness.
2. Main types include **glass, carbon, aramid, natural, and specialty fibers**.
3. Fiber characteristics such as **length, diameter, aspect ratio, and mechanical properties** determine reinforcement efficiency.
4. Fiber **orientation and distribution** strongly influence anisotropy and directional performance.

5. Surface properties of fibers affect **matrix adhesion and stress transfer**.
 6. Different fibers are selected based on **mechanical, thermal, chemical requirements, and cost**.
 7. Applications range from **aerospace and automotive to sports and industrial composites**, depending on fiber type and properties.
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Control Questions:

1. What are fiber reinforcements and why are they effective in composites?
 2. List the main types of fibers and their specific characteristics.
 3. How do fiber length, diameter, and aspect ratio affect composite properties?
 4. Why is fiber orientation important for composite performance?
 5. What are the typical applications for glass, carbon, aramid, and natural fibers?
 6. How do fiber surface properties influence the composite's mechanical behavior?
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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).