

Discipline: Actual problems of chemistry of polymer composites

Lecture 13.

Theme: Biodegradable Polymer Composites. Natural and Synthetic Biodegradable Polymers

Objective:

To understand the **concept, types, and applications of biodegradable polymer composites**, including both **natural and synthetic biodegradable polymers**, and their role in sustainable materials.

Key Questions:

1. What are biodegradable polymers, and why are they important?
 2. What are the main natural biodegradable polymers and their properties?
 3. What are the main synthetic biodegradable polymers and their properties?
 4. How are biodegradable polymer composites designed and manufactured?
 5. What are the applications of biodegradable polymer composites in different industries?
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Lecture Content:

- **Introduction to Biodegradable Polymers:**
 - Biodegradable polymers are **polymers capable of being broken down by microorganisms into water, carbon dioxide, and biomass**.
 - Importance: **reducing environmental pollution, replacing conventional plastics, and enabling sustainable materials**.
- **Natural Biodegradable Polymers:**
 - **Polysaccharides:** starch, cellulose, chitosan, alginate.
 - Advantages: renewable, biocompatible.
 - Limitations: poor mechanical properties, moisture sensitivity.
 - **Proteins:** gelatin, collagen, silk fibroin.
 - Used in **medical applications, packaging, and tissue engineering**.
- **Synthetic Biodegradable Polymers:**
 - **Aliphatic polyesters:** polylactic acid (PLA), polycaprolactone (PCL), polyglycolide (PGA), polyhydroxybutyrate (PHB).

- Advantages: tunable degradation rate, good mechanical properties.
- Limitations: higher cost, sometimes lower processability than conventional plastics.
- **Polyester blends and copolymers:** PLA-PCL, PLA-PHA, PGA-PLA copolymers.
 - Tailored properties: improved flexibility, degradation rate, and mechanical strength.
- **Biodegradable Polymer Composites:**
 - Formed by **reinforcing biodegradable polymers** with fibers, particles, or natural fillers (e.g., cellulose, starch, nanoclays).
 - Design considerations: **mechanical performance, degradation rate, environmental impact.**
 - Methods of fabrication: **melt blending, solution casting, extrusion, and injection molding.**
- **Factors Influencing Biodegradability:**
 - **Chemical structure:** ester, amide, or ether linkages.
 - **Molecular weight:** lower molecular weight enhances degradation.
 - **Crystallinity:** amorphous regions degrade faster than crystalline regions.
 - **Environmental conditions:** temperature, humidity, pH, presence of microorganisms.
- **Applications:**
 - **Medical:** sutures, drug delivery systems, tissue scaffolds.
 - **Packaging:** biodegradable films, bags, disposable containers.
 - **Agriculture:** mulch films, controlled-release fertilizers.
 - **Environmental engineering:** eco-friendly composites for temporary structures.

Key Short Theses:

1. Biodegradable polymers can be **degraded by microorganisms into harmless products.**
2. Natural biodegradable polymers include **polysaccharides and proteins**; synthetic include **aliphatic polyesters and copolymers.**
3. Biodegradable polymer composites combine a **biodegradable matrix with reinforcements** for enhanced properties.
4. Mechanical and degradation properties depend on **chemical structure, molecular weight, crystallinity, and environmental conditions.**
5. Fabrication methods include **melt blending, solution casting, extrusion, and injection molding.**
6. Applications span **medical, packaging, agricultural, and environmental sectors.**

7. Biodegradable composites offer a **sustainable alternative to conventional plastics** while enabling tailored properties for specific uses.
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Control Questions:

1. Define biodegradable polymers and explain their importance.
 2. Name three natural biodegradable polymers and their main properties.
 3. Name three synthetic biodegradable polymers and their applications.
 4. How are biodegradable polymer composites typically fabricated?
 5. What factors influence the degradation rate of biodegradable polymers?
 6. Give examples of applications of biodegradable polymer composites in medicine and packaging.
 7. What are the advantages and limitations of natural vs. synthetic biodegradable polymers?
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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).