Discipline: Actual problems of chemistry of polymer composites

Lecture 15.

Theme: Photocuring Polymer Composites and Methods for Their Obtaining

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Objective:

To understand the **principles, types, and methods of producing photocuring polymer composites**, and to analyze how light-activated curing influences the properties and applications of polymer-based materials.

Key Questions:

1. What are photocuring polymer composites, and how do they work?
2. What types of polymers and fillers are used in photocuring composites?
3. What methods are used to fabricate photocuring polymer composites?
4. How does photocuring affect the mechanical and chemical properties of composites?
5. What are the practical applications of photocuring polymer composites?

Lecture Content:

- **Introduction to Photocuring Polymer Composites:**
  - Photocuring polymer composites are **materials in which a polymer matrix undergoes polymerization or cross-linking under the action of light** (UV, visible, or near-IR).
  - Advantages: **rapid curing, energy efficiency, spatial control of polymerization, and ability to form complex shapes**.
  - Common applications: coatings, adhesives, 3D printing, dental materials, and electronic encapsulants.
- **Polymer Matrices for Photocuring:**
  - **Acrylics:** acrylates and methacrylates (monomers and oligomers).
  - **Epoxy acrylates:** combination of epoxy and acrylic properties.
  - **Vinyl ethers and thiol-ene systems:** fast curing, low shrinkage.
- **Fillers and Additives:**
  - **Dispersed fillers:** silica, glass, mineral powders for mechanical reinforcement.
  - **Fibrous fillers:** short glass fibers or carbon fibers for structural reinforcement.

    - **Nanoparticles:** TiO_2, ZnO, or clay for improved thermal, mechanical, and barrier properties.
    - **Photoinitiators:** compounds that generate radicals or cations under light to initiate polymerization.
- **Methods of Obtaining Photocuring Polymer Composites:**
    1. **UV or Visible Light Curing:**
        - The composite mixture (monomers + fillers + photoinitiators) is exposed to UV or visible light.
        - Radical or cationic polymerization is initiated by the photoinitiator.
        - Fast curing (seconds to minutes) suitable for coatings and adhesives.
    2. **Photolithography / Patterned Curing:**
        - Light is applied through masks to **create patterned or microstructured composites**.
        - Used in electronics, microfluidics, and biomedical scaffolds.
    3. **3D Printing / Stereolithography (SLA) and Digital Light Processing (DLP):**
        - Layer-by-layer curing of resin containing photoinitiators and fillers.
        - Enables **high-resolution, complex geometries** for functional components.
    4. **In-situ Incorporation of Fillers:**
        - Fillers are dispersed into the photocurable resin before curing.
        - Ensures **uniform distribution and strong interfacial bonding**.
- **Factors Affecting Properties:**
    - **Photoinitiator type and concentration:** affects curing rate and depth.
    - **Filler type, size, and loading:** influences mechanical, thermal, and optical properties.
    - **Light intensity and exposure time:** determine the degree of conversion and final composite properties.
- **Applications:**
    - **Coatings and adhesives:** rapid curing, durable surfaces.
    - **Dental materials:** fillings, sealants, and bonding agents.
    - **3D-printed structural components:** electronics, prototypes, and biomedical scaffolds.
    - **Functional composites:** optical, magnetic, or conductive properties introduced via fillers.

Key Short Theses:

1. Photocuring polymer composites rely on **light-induced polymerization** to rapidly form solid materials.

2. Polymer matrices include **acrylates, epoxy acrylates, vinyl ethers, and thiol-ene systems**.
3. Fillers and additives provide **mechanical reinforcement, functional properties, and enhanced processability**.
4. Methods include **UV/visible light curing, photolithography, 3D printing, and in-situ filler incorporation**.
5. Properties are influenced by **photoinitiator type, filler characteristics, and curing conditions**.
6. Applications span **coatings, adhesives, dental materials, 3D printing, and functional composites**.
7. Photocuring enables **rapid, energy-efficient, and spatially controlled fabrication** of polymer composites.

Control Questions:

1. Define photocuring polymer composites and explain their working principle.
2. List the main types of photocurable polymer matrices.
3. What types of fillers are commonly used in photocuring composites?
4. Describe three methods for obtaining photocuring polymer composites.
5. How do light intensity and exposure time affect composite properties?
6. Give examples of applications in dental materials and 3D printing.
7. Why is uniform filler distribution important in photocuring 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).