Discipline: Actual problems of chemistry of polymer composites

Lecture 8.

Theme: Adhesion and Cohesion. Types of Bonding Components in Polymer Composites

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Objective:

To understand the concepts of **adhesion and cohesion**, their roles in polymer composites, and the **types of bonding** that govern the interaction between the matrix and reinforcement.

Key Questions:

1. What is the difference between adhesion and cohesion in polymer composites?
2. What are the main types of bonds between matrix and reinforcement?
3. How do physical and chemical interactions affect composite properties?
4. How can bonding be enhanced to improve composite performance?

Lecture Content:

- **Adhesion vs. Cohesion:**
  - **Cohesion:** Internal forces that hold together molecules within the **same material**.
    - Responsible for the **structural integrity of the polymer matrix**.
    - Examples: van der Waals forces, hydrogen bonding, covalent bonds within the polymer.
  - **Adhesion:** Forces that bind **different materials** together, such as matrix to fiber or particle.
    - Determines **stress transfer efficiency** from matrix to reinforcement.
    - Strong adhesion prevents delamination and interfacial failure.
- **Types of Bonding Components in Polymer Composites:**
  1. **Physical Bonds:**
     - **Van der Waals interactions:** Weak, non-specific forces between molecules.
     - **Hydrogen bonding:** Stronger than van der Waals, directional bonding.

        - **Electrostatic interactions:** Occur if reinforcement has surface charges.
        - Influence wettability, interphase formation, and reversible adhesion.
    2. **Chemical Bonds:**
        - **Covalent bonding:** Strong, permanent bonds between matrix and reinforcement.
        - Often achieved via **surface functionalization** or **coupling agents**.
        - Provides high interfacial strength and improved mechanical properties.
    3. **Mechanical Interlocking:**
        - Physical anchoring of the matrix into surface **roughness, pores, or fibers**.
        - Enhances adhesion without chemical modification.
    4. **Interphase Formation:**
        - Region where **properties of the polymer matrix gradually change near the reinforcement**.
        - Combines physical, chemical, and mechanical interactions.
        - Critical for **toughness, impact resistance, and durability**.
- **Factors Affecting Bonding:**
    - Surface energy of reinforcement.
    - Surface roughness and morphology.
    - Chemical functionality and polarity.
    - Processing conditions (temperature, pressure, curing).
    - Use of **compatibilizers or coupling agents**.
- **Applications:**
    - Strong adhesion ensures **high-performance structural composites** in aerospace, automotive, and sports equipment.
    - Optimized bonding reduces defects such as **delamination, fiber pull-out, and void formation**.

Key Short Theses:

1. **Cohesion** keeps the polymer matrix intact; **adhesion** binds the matrix to reinforcement.
2. Effective stress transfer requires **strong adhesion at the interface**.
3. Types of bonding include **physical interactions, chemical bonds, and mechanical interlocking**.
4. Physical bonds (van der Waals, hydrogen bonding) are reversible but contribute to wettability and interphase formation.
5. Chemical bonds (covalent) provide **permanent interfacial strength**.

6. Mechanical interlocking enhances adhesion through **surface roughness and porosity**.
7. Interphase formation integrates multiple bonding mechanisms to improve **composite durability and toughness**.

Control Questions:

1. Define cohesion and adhesion in the context of polymer composites.
2. What are the main types of bonding between matrix and reinforcement?
3. How do physical bonds differ from chemical bonds?
4. What is mechanical interlocking, and how does it enhance adhesion?
5. Why is interphase formation important for composite performance?
6. Which factors influence the strength of adhesion in polymer 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).