Discipline: Actual problems of chemistry of polymer composites

Lecture 7.

Theme: Theoretical Basis for Obtaining Polymer Composites. Interface and Interphase Bond. Wettability as Main Criteria for Obtaining Polymer Composites

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Objective:

To understand the **theoretical principles of polymer composite formation**, focusing on **interface and interphase bonding**, and to examine **wettability as a critical factor** in achieving effective composite performance.

Key Questions:

1. What is the role of the interface in polymer composites?
2. What is the interphase region and how does it affect composite properties?
3. How does wettability influence the interaction between matrix and reinforcement?
4. What are the main factors governing adhesion in polymer composites?
5. How can interface and interphase properties be optimized?

Lecture Content:

- **Theoretical Basis of Polymer Composites Formation:**
  - Polymer composites consist of **reinforcements embedded in a polymer matrix**, forming a material with improved mechanical, thermal, and functional properties.
  - The **quality of the bond between matrix and reinforcement** strongly determines composite performance.
- **Interface and Interphase Bond:**
  - **Interface:** The surface contact region between the reinforcement and the polymer matrix.
    - Responsible for **stress transfer** from the matrix to the reinforcement.
    - Poor interface leads to **weak points and reduced mechanical performance**.
  - **Interphase:** A transition layer surrounding the reinforcement where the polymer properties differ from the bulk matrix.

        - Its thickness and properties affect **adhesion, toughness, and durability**.
        - Formed due to **physical adsorption, chemical bonding, or entanglement** of polymer chains.
- **Wettability and Its Importance:**
    - **Wettability** is the ability of a liquid polymer matrix to **spread over and adhere to the reinforcement surface**.
    - High wettability ensures **good contact, improved adhesion, and uniform stress distribution**.
    - Factors influencing wettability:
        - Surface energy of reinforcement
        - Surface roughness
        - Surface chemistry (hydrophilic or hydrophobic properties)
        - Temperature and viscosity of the polymer melt or solution
- **Criteria for Effective Composite Formation:**
    - Optimal interface and interphase properties for **efficient stress transfer**.
    - Adequate wettability to ensure **complete impregnation of fibers or particles**.
    - Surface treatments (coupling agents, plasma treatment, chemical modification) to improve adhesion.
- **Practical Considerations:**
    - Poor wettability leads to **voids, debonding, and reduced mechanical strength**.
    - Interphase properties can be engineered by **surface modification of reinforcements or matrix additives**.
    - The combination of **interface strength, interphase thickness, and wettability** determines **composite durability, toughness, and thermal stability**.
- **Applications:**
    - Aerospace and automotive composites require **strong interphase bonding** for high performance.
    - Structural polymer composites rely on **optimized wettability and interface adhesion**.
    - Nanocomposites emphasize interphase engineering due to the high surface area of nanoparticles.

Key Short Theses:

1. The **interface** is the immediate contact region between reinforcement and matrix, crucial for stress transfer.
2. The **interphase** is a transition layer with properties different from the bulk matrix, affecting toughness and adhesion.

3. **Wettability** is a key factor for effective polymer-reinforcement bonding.
4. High surface energy, proper surface chemistry, and controlled processing improve wettability.
5. Surface treatments or coupling agents enhance **interface and interphase adhesion**, leading to improved composite performance.
6. Optimizing interface, interphase, and wettability is essential for **mechanical strength, durability, and functional properties**.
7. Poor interface or insufficient wettability leads to voids, delamination, and reduced composite quality.

Control Questions:

1. What is the difference between the interface and interphase in polymer composites?
2. How does interphase thickness affect composite properties?
3. Why is wettability critical in obtaining high-performance polymer composites?
4. Which factors influence wettability of polymer matrices on reinforcements?
5. How can surface treatments improve interface and interphase bonding?
6. What are the consequences of poor adhesion and wettability 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).