ITMO University

Advanced Methods of Materials Characterization

Course Workload		Assessment form (examination/ graded test/ ungraded test)
ECTS	Hours	
6	216	Exam

Students will know physical phenomena underlying the methods of research and control of the composition, structure and properties of nanostructured materials; to be aware of the modern instrument base used for nanocharacterization, its main features and limitations; to describe the fundamental principles and principles of modern physical and chemical research methods.

Course structure:

1. Nanostructured materials and features of their characterization

1.1. Nanoscale objects and structures, their general classification and physicochemical features
1.2. The main methods for characterizing nanoscale objects: composition, dimension, specific surface area, shape (morphology), stability and functional response
1.3. Variety of modern methods and approaches of nanocharacterization (general overview and comparative analysis)
1.4. Review of modern devices used for nanomaterials characterization

2. Methods of transmission and scanning electron microscopy

2.1. The device and operation principle of an electron microscope
2.2. The main units of an electron microscope, their capabilities and limitations in the method resolution
2.3. Transmission and scanning (raster) electron microscopy
2.4. Possibilities of substances structural analysis by transmission microscopy
2.5. Capabilities of additional instrument modules and analysis tools
2.6. Detectors of secondary electrons, backscattered electrons, Auger electrons, characteristic X-rays and cathodoluminescence

3. Methods based on diffraction and scattering of X-ray, synchrotron and neutron radiation

3.1. X-ray diffraction of single crystals and polycrystalline materials
3.2. Transmission and reflective radiography techniques
3.3. Neutron diffraction

3.4. Possibilities of using synchrotron radiation
3.5. Primary X-ray processing and identification of substances
3.6. Wolfe-Bragg formula
3.7. Particles' or polycrystalline materials grains' size effect on the broadening of diffraction peaks
3.8. Scherrer's formula
3.9. Possibilities of small-angle diffraction and small-angle scattering in the study of thin films and nanostructured materials

4. Optical spectroscopy methods

4.1. Phenomena of light absorption and emission by substances
4.2. Excited states of atoms and molecules, principles of light absorption and emission spectroscopy near the visible range
4.3. Basic energy states of molecules: electronic, vibrational and rotational
4.4. Quantum levels, forced transitions and energy spectra
4.5. Yablonsky diagram. Stokes shift. Singlet and triplet states
4.6. Fluorescence. Phosphorescence. Spectrophotometry and fluorimetry
4.7. Review of the main laws governing the formation of absorption and emission spectra by various molecular groups and compounds
4.8. Quantitative analysis capabilities by spectrometry and spectrofluorimetry
4.9. Bouguer-Lambert-Beer law and its practical application. Possible nonlinear deviations

5. Vibrational spectroscopy methods

5.1. Vibrational spectra of diatomic and polyatomic molecules
5.2. Energy levels of electronic states, their classification
5.3. Intensity of vibrational spectra bands
5.4. Selection rules and intensity of IR radiation absorption
5.5. Raman spectroscopy
5.6. Stokes and anti-Stokes shifts

6. Investigation of disperse systems by the method of dynamic light scattering

6.1. Colloidal solutions and suspensions
6.2. Hydrodynamic radius of particles and its relationship with mobility in viscous solutions
6.3. Brownian motion. Stokes-Einstein ratio
6.4. Determination of the particle hydrodynamic radius by the analysis of dynamic light scattering
6.5. Using autocorrelation functions to calculate the hydrodynamic radius of particles
6.6. Estimation of the statistical particle size distribution. Influence of solution parameters on measurement accuracy
6.7. Overview of the possibilities and limitations of the method
6.8. Electric double layer on particle surfaces in finely dispersed systems
6.9. Stability of colloidal solutions
6.10. Zeta potential, main approaches to its definition
6.11. Comparative analysis of electrophoretic and electroacoustic methods for determining zeta potential

7. Methods for characterizing the porous structure and surface properties of materials

7.1. Low-temperature physical nitrogen sorption method
7.2. Materials with high porosity and high specific surface area
7.3. The phenomenon of surface gas adsorption and its use for quantitative characterization of the specific surface area and porosity of materials
7.4. Basic models of gas sorption-desorption under isothermal conditions. Monolayer formation
7.5. Capillary condensation processes in mesoporous structures
7.6. Langmuir isotherm. Isotherms of Temkin, Freundlich, BET model and others, peculiarities of their application in characterization by the adsorption method
7.7. Hysteresis of adsorption-desorption isotherms, its analysis for characterization of porous structures
7.8. Study of the hydrophilic-hydrophobic properties of the surface by analyzing the shape of a drop

8. Atomic force microscopy

8.1. Atomic force microscopy. Cantilever device, its mechanical characteristics
8.2. Hooke's Law. The phenomenon of mechanical resonance, determination of the cantilever natural frequencies
8.3. The main scanning modes and their capabilities: contact, non-contact, semi-contact
8.4. Topographic scanning modes: "constant height" and "constant force"