COURSE DESCRIPTION CARD - SYLLABUS

Course name

ATOMIC FORCE MICROSCOPY IN MATERIALS RESEARCH

Course

Proposed by Discipline	Year/Semester
Materials engineering	II/4
Type of studies	Course offered in
Doctoral School	English
Form of study	Requirements
full-time	elective

Number of hours

Lecture	Tutorials	Projects/seminars
8		

Number of credit points

2

Lecturers

Responsible for the course/lecturer:

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Responsible for the course/lecturer:

Prerequisites

Knowledge: basic knowledge of the core course of physics and chemistry.

Skills: knowledge and ability to analyze experimental data.

Social competencies: understanding the need to extend the level of competence; responsibility for own work.

Course objective

1. Acquaint the PhD students with the idea and measuring capabilities of the most comprehensive tool for characterizing materials at the micro and nanometer scale.

2. Present basic atomic force microscopy (AFM) techniques and AFM-derived methods commonly used in materials research.

3. Develop students' competencies to formulate and solve problems in physics, chemistry, materials science and engineering.

Course-related learning outcomes

Knowledge

A PhD student who graduated from doctoral school knows and understands:

1) recent achievements in the characterization of materials at the level of single molecules and atoms, [P8S_WG/SzD_W01]

2) basic methods and techniques of atomic force microscopy, in particular the type of information they provide, and can compare AFM with other methods used in the study of materials at the nanometer and atomic scale such as scanning tunneling microscopy (STM) and electron microscopy (SEM, TEM). [P8S_WG/SzD_W02], [P8S_WG/SzD_W03]

Skills

A PhD student who graduated from doctoral school can:

1) precisely formulate research problems and propose ways to solve them, including choosing right measurement methods to obtain useful information about studied materials, [P8S_UW/SzD_U01]

2) analyze images and force curves recorded by atomic force microscope to obtain information about specific (mechanical, physical, chemical, etc.) properties of the studied materials at the nanoscale., [P8S_UW/SzD_U02], [P8S_UK/SzD_U04]

Social competences

A PhD student who graduated from doctoral school is ready to:

1) critically acquire knowledge from various sources, including online resources, [P8S_KK/SzD_K01], [P8S_KK/SzD_K03]

2) able to assess the relationship between his/her own research and the world achievements in a given scientific discipline. [P8S_KK/SzD_K01], [P8S_KK/SzD_K02]

Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

PQF code	Methods for verification of learning outcomes	Assessment criteria
W01, W02, W03	Activity, test - quiz	sufficient – 50.1%-70.0%, good – 70.1%-90.0%, very good – > 90.1%
U01, U02, U04	Evaluation of students' presentations on subjects related to the lecture	sufficient – 50.1%-70.0%, good – 70.1%-90.0%, very good – > 90.1%
K01, K02, K03	Evaluation of students' presentations on subjects related to the lecture	sufficient – 50.1%-70.0%, good – 70.1%-90.0%, very good – > 90.1%

Programme content

This course focuses on atomic force microscopy (AFM) and its related techniques for imaging and characterizing materials. Students will learn about the construction and operation of AFM, including key operating modes and surface imaging techniques. The course covers image analysis, identifying common artefacts, and understanding atomic force spectroscopy and dynamic force spectroscopy. Additionally, related methods for analyzing selected physical and chemical properties will be explored. Examples for various materials such as crystals, polymers, biomaterials, and single molecules, will be provided. The course concludes with a comparison of AFM to other imaging and characterization methods, providing a broader context for understanding materials analysis.

Course topics

1. Introduction and general classification of the methods for imaging and characterization of materials (obtaining information about the world around us, microscopic methods, spectroscopic methods).

2. Construction and operation of an atomic force microscope (AFM): detection system, piezoelectric scanner, feedback loop.

3. Basic operating modes and surface imaging techniques: contact (static) technique, intermittent-contact technique, and non-contact technique.

4. Image analysis; common causes of artefacts: non-linearity of piezoelectric scanners, mapping of the tip, incorrect feedback loop settings, incorrect image processing, external interference (mechanical, acoustic, electrical or optical), thermal drift, examples of images for various types of materials: crystals, polymers, biological samples, etc.

5. Atomic force spectroscopy: calibration of the cantilever, relation between the force curve and the interaction potential, analysis of force curves, examples for various samples, including single molecules.

6. Dynamic force spectroscopy: force modulation spectroscopy, spectroscopy at different separation rates, type of information obtained with these methods.

7. Dynamic AFM imaging methods for material contrast: phase contrast microscopy, force modulation microscopy, type of information obtained using the above methods.

8. Related methods and derivatives of AFM for information on selected physical and chemical properties of materials: friction force microscopy, magnetic force microscopy, electrostatic force microscopy, thermal conductivity microscopy, electrochemical potential microscopy, spin-sensitive microscopy.

9. Molecular modeling and simulations as complementary methods to AFM, allowing for obtaining information about the structure and electronic properties of materials at the molecular scale.

10. Comparison of atomic force microscopy and spectroscopy with other methods of imaging and characterizing materials (optical, near-field, electron, ion, and tunneling microscopies and spectroscopies as well as diffraction methods), summary and general conclusions.

Teaching methods

Lecture: multimedia presentation including illustrations and examples.

Bibliography

Basic

1. Original lecture materials made available for PhD students by the lecturer.

2. A practical guide to scanning probe microscopy, R. Howland, L. Benatar, Park Scientific Instruments 2002.

3. Nanoscale Science and Technology, red. R. W. Kelsall, I. W. Hamley, M. Geoghegan, John Wiley & Sons Ltd 2005.

Additional

1. Atomic Force Microscopy: Understanding Basic Modes and Advanced Applications, Greg Haugstad, John Wiley & Sons, 2012.

2. Atomic Force Microscopy, P. Eaton and P. West, Oxford University Press, Oxford 2010.

3. Nanoscience: Nanotechnologies and Nanophysics, C. Dupas, Ph. Houdy, M. Lahmani (Eds), Springer-Verlag, Berlin 2007.

Breakdown of average student's workload

	Hours	ECTS
Total workload	50	2,0
Classes requiring direct contact with the teacher	8	0
Doctoral student's own work (literature studies, preparation for tutorials, project preparation) [1]	42	2,0

[1] delete or add other activities as appropriate