



## COURSE DESCRIPTION CARD - SYLLABUS

Course name

ATOMIC FORCE MICROSCOPY IN MATERIALS RESEARCH

### Course

Proposed by Discipline

Materials engineering

Type of studies

Doctoral School

Form of study

full-time

Year/Semester

II/4, III/6

Course offered in

English

Requirements

elective

### Number of hours

Lecture

4

Tutorials

Projects/seminars

### Number of credit points

1

### Lecturers

Responsible for the course/lecturer:

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Physics

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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	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

1. Introduction and general classification of the methods for imaging and characterization of materials (getting 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 techniques of surface imaging (contact (static) technique, intermittent-contact technique, non-contact technique).
4. Image analysis; common causes of artifacts (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. 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	22	1.0
Classes requiring direct contact with the teacher	6	0.5
Student's own work (literature studies, preparation for tutorials, project preparation) <sup>1</sup>	16	0.5

<sup>1</sup> delete or add other activities as appropriate