COURSE DESCRIPTION CARD - SYLLABUS

Course name
ATOMIC FORCE MICROSCOPY AND SPECTROSCOPY IN MATERIALS RESEARCH [S5IMAT>MSSABM]

Course

Proposed by Discipline
–

Year/Semester
2/4

Level of study
Doctoral School

Course offered in
English

Form of study
full-time

Requirements
elective

Number of hours

Lecture
8

Laboratory classes
0

Other
0

Tutorials
0

Projects/seminars
0

Number of credit points

2,00

Coordinators

dr hab. Arkadiusz Ptak prof. PP
arkadiusz.ptak@put.poznan.pl

Lecturers

dr hab. Arkadiusz Ptak prof. PP
arkadiusz.ptak@put.poznan.pl

Prerequisites

Knowledge: A foundation in physics and chemistry at the undergraduate level. Skills: Ability to analyse and interpret experimental data. Social competences: Awareness of the need for continuous professional development and responsibility for one's own work.

Course objective

1. Introduce doctoral students to the operating principles and measurement capabilities of atomic force microscopy (AFM) for characterising materials at the micro- and nanoscale. 2. Present the main AFM imaging and measurement techniques, as well as related methods used in materials research. 3. Develop students' ability to select appropriate AFM methods and interpret their results when addressing research problems in physics, chemistry, and materials science and engineering.

Course-related learning outcomes

Knowledge
Upon completion of the course, the doctoral student knows and understands:
1. Recent advances and current research trends in the characterisation of materials at the single-molecule and atomic scales. [P8S_WG / SzD_W01, SzD_W02]
2. The principles and main techniques of atomic force microscopy (AFM), the information they provide, and

how AFM compares with other methods used to study materials at the nanoscale, including scanning tunnelling microscopy (STM) and electron microscopy (SEM and TEM). [P8S_WG / SzD_W03]

Skills
Upon completion of the course, the doctoral student can:
1. Formulate a research problem and select appropriate measurement methods to investigate the properties of a material. [P8S_UW / SzD_U01]
2. Analyse and interpret AFM images and force curves to investigate the mechanical and other physical or chemical properties of materials at the nanoscale. [P8S_UW / SzD_U01, SzD_U02]

Social competences
Upon completion of the course, the doctoral student is ready to:
1. Critically assess published research findings in the field of nanoscale material characterisation. [P8S_KK / SzD_K01]
2. Critically assess how their own research relates to, and contributes to, current research in their discipline. [P8S_KK / SzD_K01, SzD_K02]

Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

Knowledge
Learning outcome code: SzD_W01, SzD_W02, SzD_W03.
Methods for verification of learning outcomes: Quiz assessing knowledge of recent advances, AFM techniques and their comparison with other microscopy methods.
Assessment criteria: Percentage of correct answers, graded according to the adopted grading scale.

Skills
Learning outcome code: SzD_U01, SzD_U02.
Methods for verification of learning outcomes: Presentation or assignment in which the doctoral student selects a method for a stated research problem and analyses sample AFM images and force curves.
Assessment criteria: Appropriateness of the selected method; correctness of data analysis and interpretation; justification of conclusions.

Social competences
Learning outcome code: SzD_K01, SzD_K02.
Methods for verification of learning outcomes: Critical discussion of selected publications and, where applicable, the relationship of the doctoral student’s own research to current work in the field.
Assessment criteria: Ability to assess the evidence and limitations of published findings and to place one’s own research in context.

Programme content

The course introduces atomic force microscopy (AFM) as a method for imaging and characterising materials at the micro- and nanoscale. It covers the main components and operating principles of an AFM, its principal imaging modes, and the analysis of images, including the recognition of common artefacts. Further topics include force spectroscopy, dynamic force spectroscopy, and AFM-based methods for investigating selected physical and chemical properties. Applications are illustrated with examples involving crystalline materials, polymers, biomaterials, and individual molecules. The course also compares AFM with other methods for imaging and characterising materials.

Course topics

1. Introduction to materials characterisation: classification of imaging and spectroscopic methods and the information they provide.
2. Construction and operation of an atomic force microscope (AFM): detection system (cantilever and tip, deflection detection), piezoelectric scanner, and feedback control.
3. Principal AFM imaging modes: contact, intermittent-contact, and non-contact modes.
4. AFM image analysis: interpretation of images and recognition of common artefacts caused by scanner nonlinearity, tip geometry, feedback settings, image processing, external interference, and thermal drift. Examples of images involving crystalline materials, polymers, and biological samples.

5. AFM force spectroscopy: cantilever calibration, acquisition and analysis of force–distance curves, the relationship between measured force and interaction potential, and examples of measurements on materials and individual molecules.
6. Dynamic force spectroscopy: measurements at different loading rates, analysis of rupture forces, and the information obtainable about molecular interactions.
7. AFM methods for material contrast: phase imaging and force modulation microscopy; interpretation and limitations of the resulting contrast.
8. AFM-based methods for investigating selected material properties: friction force microscopy, magnetic force microscopy, electrostatic force microscopy, Kelvin probe force microscopy, scanning thermal microscopy and others.
9. Computational methods complementing AFM: molecular modelling and simulation of structure and interactions; electronic-structure calculations where electronic properties are discussed.
10. Comparison with other characterisation methods: scanning tunnelling microscopy and spectroscopy, optical and near-field microscopy, electron microscopy and spectroscopy, diffraction methods. Summary of the capabilities and limitations of AFM.

Teaching methods

Lectures supported by multimedia presentations, with examples of AFM images, force–distance curves, and their interpretation.

Bibliography

Basic
1. Lecture materials provided to doctoral students by the lecturer.
2. G. Haugstad, Atomic Force Microscopy: Understanding Basic Modes and Advanced Applications, John Wiley & Sons, 2012.
3. P. Eaton and P. West, Atomic Force Microscopy, Oxford University Press, 2010.

Additional
1. R. Howland and L. Benatar, A Practical Guide to Scanning Probe Microscopy, Park Scientific Instruments 2002.
2. K. Bian et al., “Scanning probe microscopy”, Nature Reviews Methods Primers 1, 36 (2021), DOI: 10.1038/s43586-021-00033-2
3. R. W. Kelsall, I. W. Hamley and M. Geoghegan (eds.), Nanoscale Science and Technology, John Wiley & Sons, 2005.
4. C. Dupas, P. Houdy and M. Lahmani (eds.), Nanoscience: Nanotechnologies and Nanophysics, Springer, 2007.

Breakdown of average student's workload

	Hours	ECTS
Total workload	50	2,00
Classes requiring direct contact with the teacher	8	0,00
Doctoral student's own work (literature studies, preparation for laboratory classes/tutorials, preparation for tests/exam, project preparation)	42	2,00