POZNAN UNIVERSITY OF TECHNOLOGY

EUROPEAN CREDIT TRANSFER AND ACCUMULATION SYSTEM (ECTS)

COURSE DESCRIPTION CARD - SYLLABUS

Course name
SCANNING TUNNELING MICROSCOPY [S5IMAT>STM]

Course

Proposed by Discipline
–

Year/Semester
3/5

Level of study
Doctoral School

Course offered in
English

Form of study
full-time

Requirements
elective

Number of hours

Lecture
4

Laboratory classes
0

Other
0

Tutorials
0

Projects/seminars
0

Number of credit points

1,00

Coordinators

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Lecturers

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Prerequisites

Knowledge: basic knowledge of the core course of physics and chemistry. Skills: knowledge and ability to analyze experimental data. Social competencies: understanding of the need to extend the level of competence; responsibility for the own work.

Course objective

1. Familiarize PhD students with the techniques of scanning tunneling microscopy (STM) , commonly used in characterization of surfaces and nanostructures. 2. Developing PhD students' competencies to formulate and solve problems in physics and materials engineering at the nanometer scale.

Course-related learning outcomes

Knowledge
A PhD student who graduated from doctoral school knows and understands:
1) global achievements, covering theoretical foundations as well as general and selected specific issues that are relevant to scanning tunneling microscopy, can describe the type of information they provide such as atomic structure of surfaces and nanostructures, their local electronic properties (LDOS), magnetic properties at the nano- and subnano-meter scale, [P8S_WG/SzD_W01], [P8S_WG/SzD_W02],
2) the tunnel effect, its application in micro- and nano-scopy, can understand physical interpretation of the STM images and the related phenomena, [P8S_WG/SzD_W03],

3) principles of disseminating results of scientific activity in the field of the STM, also in an open access mode, [P8S_WG/SzD_W04],
4) economic, legal, ethical and other vital conditions related to scientific activity in the field of the STM, especially connected with manipulation matter on the atomic scale. [P8S_WK/SzD_W06].

Skills
A PhD student who graduated from doctoral school can:
1) analyze atomic structure of surfaces and nanostructures and correlate STM images with the local (at the atomic scale) electronic structure, and draw conclusions on the basis of research results, [P8S_UW/SzD_U01],
2) share results on professional level and also in a popular form inside Poland and abroad using the English language, [P8S_UK/SzD_U04], [P8S_UK/SzD_U05], [P8S_UK/SzD_U08].

Social competences
A PhD student who graduated from doctoral school is ready to:
1) acquire critically knowledge from a variety of sources, including Internet resources, [P8S_KK/SzD_K01],
2) precisely formulate problems and propose ways to resolve them, also in collaboration with team members. [P8S_KK/SzD_K03],
3) to initiate actions in the public interests as regards applications of the most modern techniques e.g. nanotechnology in the most important and advanced industries acting in an entrepreneurial manner but respecting the principle of public ownership of the results of scientific activities. [P8S_KO/SzD_K05], [P8S_KO/SzD_K06], [P8S_KR/SzD_K07].

Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

W01, W02, W03, W04, W06
Methods for verification of learning outcomes
Written exam - mark weight (significance): 0.6
Assessment criteria
sufficient – 50.1%-70.0%, good – 70.1%-90.0%, very good – > 90.1%

U01, U04, U05, U08
Methods for verification of learning outcomes
Written exam - mark weight (significance): 0.3
Assessment criteria
sufficient – 50.1%-70.0%, good – 70.1%-90.0%, very good – > 90.1%

K01, K03, K05, K06, K07
Methods for verification of learning outcomes
Written exam (evaluation of the litearature sources indicated by PhD student) - mark weight (significance): 0.1
Assessment criteria
sufficient – 50.1%-70.0%, good – 70.1%-90.0%, very good – > 90.1%

Alternative method for verification of learning outcomes: preparing the 3 to 6 pages (A4) hand written essay based on 3 to 5 current scientific articles devoted to topical issues on STM/S applications in the own research area published in a high rank scientific Journals (Science, Nature group journals, etc.) or on the most spectacular applications of the STM/S e.g. in spintronics, quantum electonic devices, etc.
Assessment criteria
sufficient – 50.1%-70.0%, good – 70.1%-90.0%, very good – > 90.1% as regards content of used of Ph.D. students scientific sources (e.g. sientific journals' articles.

Programme content

1. General classification of the methods for imaging and characterization of materials with the focus on materials' surfaces.
2. Construction and operation of the scanning tunneling microscope (STM), basic operating modes and techniques of surface imaging (detection system, piezoelectric scanner and its calibration, feedback loop, constant current and constant height modes).

3. Image analysis and physical interpretation of the STM images; common causes of artifacts (revealing and analysis of the atomic structure of non-reconstructed and reconstructed surfaces, non-linearity of the scanner, mapping of the tip, incorrect feedback loop settings, incorrect image processing, thermal drift).
4. Comparison of scanning tunneling microscopy with other methods of imaging and characterization of materials (scanning/transmission electron microscopy (S/TEM); LEED/Auger Spectroscopy, optical spectroscopies, spin-sensitive microscopy and spectroscopy).

Course topics

Introduction – nanostructures, nanotechnology, SPMs
Scanning Tunneling Microscopes – “usual” profilographs?
Scanning Tunneling Spectroscopy
EC-STM – a useful instrument for exercising control over dynamic processes at surfaces
NANOENGINEERING - Manipulation with atoms, molecules and nanolitography by means of the STM
Spin-Polarized STM

Teaching methods

Lecture: multimedia presentation including illustrations and examples.

Bibliography

Basic
1. R. Wiesendanger, Scanning Probe Microscopy and Spectroscopy: Methods and Applications, Cambridge University Press (2010).
2. E. Meyer, H.J. Hug,R. Bennewitz, Scanning Probe Microscopy – The Lab on a Tip, Springer-Verlag, Berlin, 2003.
3. R. Howland, L. Benatar, A practical guide to scanning probe microscopy, Park Scientific Instruments 2002.

Additional
1. R. J. Hamers and D. F. Padowitz, “Methods of Tunneling Spectroscopy with the STM,” from Scanning Probe Microscopy and Spectroscopy: Theory, Techniques, and Applications, 2nd ed., Ed. by D. A. Bonnell, New York: Wiley-VCH, Inc., 2001.
2. 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	25	1,00
Classes requiring direct contact with the teacher	4	0,00
Doctoral student's own work (literature studies, preparation for laboratory classes/tutorials, preparation for tests/exam, project preparation)	21	1,00