



## Fabrication and characterization of nanonstructures

### Educational subject description sheet

#### Basic information

<b>Study programme</b> Fizyka	<b>Didactic cycle</b> 2023/24
<b>Speciality</b> BIOFIZYKA MOLEKULARNA	<b>Subject code</b> 04FIZBMOS.22S.03335.23
<b>Organizational unit</b> Faculty of Physics	<b>Lecture languages</b> English
<b>Study level</b> Second-cycle programme	<b>Course type</b> Elective
<b>Study form</b> Full-time	<b>Block</b> specialty subjects
<b>Education profile</b> General academic	
<b>Subject coordinator</b>	Mateusz Kempieński
<b>Lecturer</b>	Mateusz Kempieński
<b>Period</b> Semester 2	<b>Activities and hours</b> • Lecture: 30, Exam • Laboratories: 30, Graded credit
	<b>Number of ECTS points</b> 5

#### Goals

Code	Goal
C1	Students will be acquainted with experimental techniques utilized in fabrication and analysis of various conducting nanostructures: thin films, wires, dots, pillars and 3D textures, including carbon-based materials.
C2	Students will be acquainted with the basic properties of nanostructured and low-dimensional materials.
C3	Students will be presented with the problems regarding the reading and understanding the experimental data obtained in the presented techniques as well as choosing the techniques relevant to specific applications

## Subject learning outcomes

Code	Outcomes in terms of	Learning outcomes	Examination methods
<b>Knowledge - Student:</b>			
W1	knows the operation principles of the physical and chemical vapor deposition, as well as surface structurization techniques.	FIZ_K2_W01, FIZ_K2_W02, FIZ_K2_W04, FIZ_K2_W05	Oral exam, Report
W2	knows the operation principles of the analysis techniques from the following branches: - electron microscopy and diffraction, - scanning probe microscopy, - photoelectron spectroscopy, - electronic properties.	FIZ_K2_W01, FIZ_K2_W02, FIZ_K2_W04, FIZ_K2_W06	Oral exam, Report
W3	knows the most important features of carbon-based nanostructures including specific fabrication methods and analysis techniques.	FIZ_K2_W01, FIZ_K2_W04, FIZ_K2_W05, FIZ_K2_W06	Oral exam, Report
W4	has practical knowledge on: - operation and maintenance of an ultra-high vacuum chamber, - deposition of thin metallic films with the use of physical deposition techniques.	FIZ_K2_W02, FIZ_K2_W07	Oral exam, Report
<b>Skills - Student:</b>			
U1	is able to identify and perform basic analysis of images and spectra obtained with the presented techniques	FIZ_K2_U01, FIZ_K2_U03	Oral exam, Report
U2	is able to choose experimental techniques according to the specific needs, i.e. select the proper fabrication route followed by the most relevant analysis techniques.	FIZ_K2_U01, FIZ_K2_U02, FIZ_K2_U03	Oral exam, Report
U3	is able to prepare samples and identify apparatus parameters for thin film deposition.	FIZ_K2_U01, FIZ_K2_U03	Oral exam, Report
U4	is able to perform basic characterization of obtained thin films with the use of AFM technique.	FIZ_K2_U01, FIZ_K2_U03	Oral exam, Report
<b>Social competences - Student:</b>			
K1	understands the complexity of the presented techniques and the role of qualified technical staff in operating the ultra-high vacuum equipment.	FIZ_K2_K01, FIZ_K2_K02	Oral exam, Report
K2	is able to cooperate in the fabrication and basic analysis of thin films under supervision of experienced lab technician.	FIZ_K2_K01, FIZ_K2_K02	Oral exam, Report

## Study content

No.	Course content	Subject learning outcomes	Activities
1.	Basic issues of physics of conductors; electric transport and localization phenomena; metal-insulator transitions; conducting nanostructures.	W1, W2, W3	Lecture
2.	Physics of vacuum, vacuum technologies (pumps, gauges, etc.).	W1, W2, W4, U1, U2, K1, K2	Lecture, Laboratories

No.	Course content	Subject learning outcomes	Activities
3.	Vapor deposition techniques (PVD, CVD, ALD, MBE).	W1, W3, W4, U1, U2, U3, K1, K2	Lecture, Laboratories
4.	Surface structurization techniques (IBS, GLAD, thermal reconstruction).	W1, U2, K1	Lecture
5.	Introduction to electron microscopy (TEM, SEM), spectroscopy (EDS) and diffraction (LEED, RHEED).	W2, U1, U2, K1	Lecture
6.	Introduction to scanning probe microscopy (STM, AFM and related techniques).	W2, W3, U1, U2, U4	Lecture, Laboratories
7.	Photoelectron spectroscopy (XPS, UPS, Auger).	W2, W3, U1, U2, K1	Lecture

### Additional information

Activities	Teaching and learning methods and activities
Lecture	Lecture with a multimedia presentation of selected issues, Laboratory method, Demonstration and observation
Laboratories	Lecture with a multimedia presentation of selected issues, Laboratory method, Demonstration and observation

Activities	Credit conditions
Lecture	Student must answer the questions regarding at least three different topics that were discussed during the lectures. The final grade will be determined based on the answers. Basic knowledge of the topic-related keywords and definitions will be rated as 3. Basic knowledge plus the ability to explain the details of the topic-related phenomena will be rated as 4. Detailed knowledge on the given topic, with the ability to answer the problem questions will be rated as 5. Final grade will be the established as the average of all student's answers.
Laboratories	Student must present the lab report comprising the basic info about all the methods used during the lab classes, as well as the obtained results. The report is required to approach the exam.

### Literature

#### Obligatory

1. Roth, A. "Vacuum technology North Holland publishing co." Amsterdam-New York-Oxford (1976).

### Calculation of ECTS points

Activities	Activity hours*
Lecture	30
Laboratories	30
Report preparation	10

Preparation for the exam	30
Reading the indicated literature	15
Preparation for classes	10
<b>Student workload</b>	<b>Hours</b> 125
<b>Number of ECTS points</b>	<b>ECTS</b> 5

\* academic hour = 45 minutes

## Efekty uczenia się dla kierunku

Kod	Treść
FIZ_K2_K01	The graduate is ready to critically evaluate own knowledge and received content
FIZ_K2_K02	The graduate is ready to recognize the importance of knowledge in solving cognitive and practical problems and seeking expert opinion (also from other scientific disciplines) to overcome difficulties during independent problem solving
FIZ_K2_U01	The graduate can use their knowledge to formulate and solve complex and unusual problems in the field of physical sciences; select and apply appropriate methods and tools necessary to solve a given problem (including advanced IT techniques), as well as adapt existing methods and tools or develop completely new ones
FIZ_K2_U02	The graduate can find the necessary information in the professional literature, databases and other sources, in particular in scientific journals basic to physics, and perform critical analysis, synthesis and creative interpretation of the collected information
FIZ_K2_U03	The graduate can formulate and test hypotheses related to simple research problems in physics (plan and perform observations, experiments, theoretical calculations or computer simulations and critically evaluate and discuss the results obtained)
FIZ_K2_W01	The graduate knows and understands in-depth selected facts, phenomena, concepts and theories specific to physics and complex relationships between them (constituting advanced general knowledge in the field of physical sciences and representing both key and other selected issues in the field of advanced detailed knowledge in this discipline)
FIZ_K2_W02	The graduate knows and understands in-depth selected research methods and tools as well as mathematical models used in physics
FIZ_K2_W04	The graduate knows and understands main development trends in the discipline of physical sciences
FIZ_K2_W05	The graduate knows and understands the role of physical sciences in the context of fundamental dilemmas and challenges of modern civilization
FIZ_K2_W06	The graduate knows and understands basic concepts and principles in the area of industrial property protection and copyright
FIZ_K2_W07	The graduate knows and understands workplace health and safety principles to the extent that allows independent work in the research workplace