# COURSE DESCRIPTION CARD - SYLLABUS

Course name
Selected nanotechnology applications [S2FT2>WZN]

## Course

Field of study
Technical Physics

Year/Semester
1/2

Area of study (specialization)
–

Profile of study
general academic

Level of study
second-cycle

Course offered in
Polish

Form of study
full-time

Requirements
compulsory

## Number of hours

Lecture
30

Laboratory classes
0

Other
0

Tutorials
15

Projects/seminars
15

## Number of credit points

4,00

## Coordinators

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## Lecturers

## Prerequisites

Knowledge of materials engineering and physics in nanotechnology, materials and vacuum techniques. Ability to describe physical and technical problems based on knowledge, and ability to obtain information from indicated sources. Understanding the need to expand one's knowledge and competencies, and willingness to cooperate within a team.

## Course objective

1. Providing students with current knowledge in nanotechnology of materials, tools and processes and their applications and familiarizing students with the possibilities of selected experimental techniques and controlled structuring and surface modification. 2. Developing students' skills in critical analysis of their ideas, research and concepts in the context of broadly understood nanotechnology and independent design of experiments and technological processes. 3. Developing students' teamwork skills in acquiring and transferring knowledge.

## Course-related learning outcomes

Knowledge:
1. knows the achievements, challenges and limitations of selected, advanced issues of materials

engineering and physics that are used in modern research and industrial technologies
2. has extensive knowledge of the characterization and modification of materials (including two-dimensional ones) and selected, potential applications in modern engineering and technology
3. has established, detailed knowledge related to selected issues of analysis of functional materials properties at various size scales
4. knows the current state of knowledge, research and development in the field of nanotechnology, condensed phase physics, surface physics, and electronics, knows about technology transfer

Skills:
1. can obtain information from literature and databases on physical and technical issues, perform their critical analysis, integrate and formulate opinions in the following aspects: physical, technical and economic
2. can self-educate and can determine directions for further learning
3. can analyze concepts of selected, intensively developed new areas of materials engineering, assess their innovativeness and technical feasibility

Social competences:
1. can work responsibly on a multi-threaded task, independently and in a team
2. understands the need and knows the possibilities of continuous updating of supplementary knowledge and the need to improve professional and social competencies
3. is aware of the social role of a technical university graduate, and understands the need to formulate and communicate to the public information and opinions on the achievements of technical physics, materials engineering and other aspects of engineering activities

## Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

In terms of the methods used to verify the achieved learning outcomes, the following grading thresholds are applied:
50.1-60% - satisfactory;
60.1-70% - satisfactory plus;
70.1-80% - good;
80.1-90% - good plus;
from 90.1% - very good.
The grade is based on an individual written assignment and/or the assessment of an oral response.

## Programme content

Lecture:
Lecture:
1. Mass spectrometry.
2. Pressure system leak tests.
3. Clean-room laboratories.
4. Surface structuring - lithographic methods.
5. Modification of crystalline surfaces.
6. Thin film deposition methods.
7. Two-dimensional materials.
8. Experiments design.
Clasess:
Learning about various techniques of surface and volume characterization with a discussion of measurement limitations and obtained physical information, solving problems related to the selection of research techniques.
Project:
Based on input data, design of a device with planar architecture including a sequence of technological processes, selection of materials, optical structure and predicted results.

## Course topics

Lectures:
1

1. Mass spectrometry: general introduction, mass spectrometer types, ion sources, mass filters, detectors, analysis of mass spectrometry results, ICP-MS, MALDI, etc., applications.
2. Leak tests: basic leak detection techniques, industrial leak detection techniques, helium leak tests, helium leak detector - operating modes, applications.
3. Clean-room laboratories: principles of use, design and construction solutions, classifications.
4. Surface structuring - lithographic methods: definitions, basics of lithography: optical, electron, ion (FIB), dual-beam devices (SEM-FIB), multi-stage processes.
5. Modification of crystalline surfaces - elements of surface physics, surface reconstruction and relaxation, methods of obtaining reconstructed semiconductor and metallic surfaces, examples of reconstruction, and systems for surface preparation.
6. Thin film deposition methods: PVD and CVD deposition and properties, including electron beam sputtering, magnetron (DC and RF), ALD, and others., methods of controlling the thickness and quality of the produced layers.
7. Two-dimensional materials: division of layered materials, production of layered materials, properties and characterization techniques.
8. Experiment design - choosing experimental techniques depending on the expected experimental results.
CLasess: Learning about various surface and volume characterization techniques with a discussion of measurement limitations and obtained physical information, solving problem issues related to the selection of research techniques.
Project: Based on input data, design of a device with planar architecture, including:
1. Selection of materials for active channels, substrate and electrical contacts.
2. Design of a surface measurement structure.
3. Development of a structure procedure using an appropriate type of lithography, including resist selection.
4. Analysis of possible measurement results for a given measurement structure based on the physical properties of the system.
5. Presentation of the obtained results.

## Teaching methods

Lecture: multimedia presentation, presentation illustrated with examples given on the board, discussion, Oxford discussion.
Clasess: presentation of developed issues, practical exercises, discussion, Oxford discussion, problem-based learning, teamwork.
Project: solving design problems, problem-based learning, discussion, Oxford discussion, teamwork, presentation of results.

## Bibliography

Basic:
[1] J. Throck Watson, O. David Sparkman, Introduction to Mass Spectrometry: Instrumentation, Applications and Strategies for Data Interpretation, 2007 John Wiley & Sons, Ltd
[2]Koczorowski, W., Kuświk, P., Przychodnia, M., Wiesner, K., El-Ahmar, S., Szybowicz, M., Nowicki, M., Strupiński, W., Czajka, R., 2017. CMOS- compatible fabrication method of graphene-based micro devices. Materials Science in Semiconductor Processing 67, 92-97.
[3] Wiley, W. C., McLaren I. H., Rev. Sci. Instrum. 1955, 26, 1150-1157
[4] [5] H. Rottländer, W. Umrath, G. Voss, Fundamentals of leak detection, Editor: Leybold GmbH Cat. No. 199 79_VA.02, https://www.leyboldproducts.com/media/pdf/90/c7/87/Fundamentals_of_Leak_Detection_EN.pdf - dostęp 10.2024
[6] Liu, Shenghong, Wang, J., Shao, J., Ouyang, D., Zhang, W., Liu, Shiyuan, Li, Y., Zhai, T., 2022. Nanopatterning Technologies of 2D Materials for Integrated Electronic and Optoelectronic Devices. Advanced Materials 34, 1-22.
[7] W. Whyte, Cleanroom Technology: Fundamentals of Design, Testing and Operation, 2nd Edition Willey 2010, ISBN: 978-0-470-74806-0, John Wiley & Sons, Ltd
[8] W. R. Fahrner - editor Nanotechnology and Nanoelectronics Materials, Devices, Measurement Techniques, Chapter: Nanostructuring, Springer-Verlag Berlin Heidelberg 2005, https://link.springer.com/book/10.1007/b137771#toc - - dostęp 01.2022
[9] Das, S., Robinson, J.A., Dubey, M., Terrones, H., Terrones, M., 2015. Beyond Graphene: Progress in

Novel Two-Dimensional Materials and van der Waals Solids. Annual Review of Materials Research 45, 1-27.

Additional:
[1] Pfeiffer Vacuum Company, The Vacuum Technology Book - part. II, 2017
[2] A. Hałas, Technika Próżni, OWPW, Wrocław, 2017
[3] J. M. Lafferty (Editor), Foundations of Vacuum Science and Technology, Wiley, New York, 1998, ISBN: 978-0-471-17593-3

## Breakdown of average student's workload

| | Hours | ECTS |
|---|---|---|
| Total workload | 100 | 4,00 |
| Classes requiring direct contact with the teacher | 60 | 2,50 |
| Student's own work (literature studies, preparation for laboratory classes/ tutorials, preparation for tests/exam, project preparation) | 40 | 1,50 |