COURSE DESCRIPTION CARD - SYLLABUS

Course name
Selected methods and applications of nanotechnology [S2ETI2>WMiZN]

Course

Field of study
Education in Technology and Informatics

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
15

Laboratory classes
15

Other
0

Tutorials
0

Projects/seminars
0

Number of credit points

2,00

Coordinators

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Lecturers

Prerequisites

Fundamental knowledge of experimental and theoretical physics in the field of nanotechnology fundamentals, materials science, and vacuum techniques. Ability to describe physical and technical problems based on existing knowledge, and proficiency in obtaining information from specified sources. Understanding the necessity of continuous professional development (expanding knowledge and competences), and readiness to collaborate effectively within a team environment.

Course objective

1. To impart current knowledge to students in the areas of nanotechnology of layered materials, selected vacuum techniques, leak detection in pressure systems, and Clean Room technology. To familiarize students with the capabilities of selected experimental techniques as well as the controlled structuring, growth, and modification of materials. 2. To develop students' ability to critically analyze their own concepts, research, and ideas within the context of broadly defined nanotechnology, and independently design experiments. 3. To shape students' skills in teamwork concerning the acquisition and transfer of knowledge.

Course-related learning outcomes

Knowledge:
1. Knows the achievements, challenges, and limitations of selected advanced topics in materials science and physics applicable to modern technologies.
2. Has extensive knowledge of the characterisation and fabrication of technological and structural materials and their potential applications in contemporary engineering and technology.
3. Has well-established, detailed knowledge related to selected topics in the analysis of functional materials properties at the nano, micro, and macro scales.
4. Knows the current state of knowledge, research, and development in the fields of nanotechnology, condensed phase physics, surface physics, and electronics. Knows about technology transfer.

Skills:
1. Ability to source information from literature and databases concerning materials engineering and technical issues, to critically analyze this information, integrate it, and formulate opinions regarding physical and technical aspects.
2. Possesses the skill of self-learning and the ability to define directions for further education.
3. Ability to analyze concepts within selected, rapidly developing new areas of materials engineering, evaluate their innovativeness, and assess their technical feasibility.ć

Social competences:
1. Ability to work responsibly on an assigned multi-threaded task, both independently and as part of a team.
2. Understands the necessity and knows the possibilities for continuously updating and supplementing knowledge, as well as the need to raise professional and social competences.
3. Is aware of the social role of a technical university graduate, in particular, understands the need to formulate and communicate to the public information and opinions regarding the achievements of technical physics and other aspects of engineering activities.

Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

Regarding the methods used to verify achieved learning outcomes, in accordance with the study regulations
Specific Assessment Rules
The lecture grade results from an individual written assignment and/or an oral examination conducted during the final lecture session.
For project classes, the final grade will include: results of continuous verification of preparation for class and in-class activity, as well as the final grade of the prepared projects.

Programme content

Lecture:
1. Mass Spectrometry
2. Leak Testing (or Leak Detection)
3. Clean Room Technology
4. Surface Structuring - Lithography Methods
5. Methods of Thin Film Deposition
6. Two-Dimensional Materials (or 2D Materials)
Project:
Based on input data, design a simple planar device architecture (e.g., Hall sensor, TLM structure, FET) encompassing a sequence of technological processes for structuring, selection of materials, measurement structure design, and p

Course topics

Lecture
1. Mass Spectrometry: Types of spectrometers, ion sources, mass filters, detectors, analysis of mass spectrometry results, ICP-MS, MALDI, etc., applications.
2. Leak Testing: Basic leak detection techniques, industrial leak detection methods, helium leak testing, helium leak detector - modes of operation.
3. Clean Room Laboratories: Rules for use, design and operation, structural solutions, CR classifications.

4. Surface Structuring - Lithography Methods: Definitions, fundamentals of lithography: optical, electron beam (EBL), focused ion beam (FIB), dual-beam systems, multi-step processes.
5. Methods of Thin Film Deposition: Deposition using PVD and CVD techniques and their properties, including electron beam sputtering, magnetron sputtering (DC and RF), ALD, and others, methods for controlling the thickness and quality of the fabricated layers.
6. Two-Dimensional Materials (2D Materials): Classification of layered materials, fabrication of layered materials, properties, and characterization techniques.
Project
1. Based on input data, design a planar architecture device encompassing:
2. Selection of materials for active channels, substrate, and electrical contacts.
3. Design of the surface measurement structure.
4. Development of a structuring procedure using an appropriate type of lithography, including the selection of photoresists (emulsion) and other chemical reagents.
5. Analysis of possible measurement results for the given measurement structure
6. Presentations of the projects

Teaching methods

Lecture
Multimedia presentation, presentation illustrated with examples given on the board, discussion, Oxford debate (or structured debate).
Project
Solving individual design problems (or Solving individual project tasks), problem-based learning, discussion, Oxford debate (or structured debate), 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] Wiley, W. C., McLaren I. H., Rev. Sci. Instrum. 1955, 26, 1150-1157
[3] 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 - access 10.2025
[5] 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 -access 01.2025
[6] 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. https://doi.org/10.1146/annurev-matsci-070214-021034
[7] 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. https://doi.org/10.1016/j.mssp.2017.05.021
[8] 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. https://doi.org/10.1002/adma.202200734

Additional:
[1] A. Hałas, Technika Próżni, OWPW, Wrocław, 2017
[2] Pfeiffer Vacuum Company, The Vacuum Technology Book - part. II, https://www.pfeiffer-vacuum.com/filepool/file/literature/vacuum-technology-book-ii-part-2.pdf?request_locale=en_US&referer=2063 - access 01.2025
[3] J. M. Lafferty (Editor), Foundations of Vacuum Science and Technology, Wiley, New York, 1998, ISBN: 978-0-471-17593-3
[4] W. Whyte, Cleanroom Technology: Fundamentals of Design, Testing and Operation, 2nd Edition Willey 2010, ISBN: 978-0-470-74806-0, John Wiley & Sons, Ltd

Breakdown of average student's workload

	Hours	ECTS
Total workload	50	2,00
Classes requiring direct contact with the teacher	30	1,00
Student's own work (literature studies, preparation for laboratory classes/ tutorials, preparation for tests/exam, project preparation)	20	1,00