Wrocław University of Science and Technology
Doctoral School

COURSE CARD

1. Basic information

Course name in English:	Technology and application of low dimensional semiconductor structure	
Course name in Polish:	Technologia i Zastosowanie Niskowymiarowych Struktur Półprzewodnikowych	
Number of hours:	30	
Type of course:	Elective course	
Form of course:	mixed forms (combination of lecture, seminar and laboratory)	
Code of course:		
Course leader:	prof. dr hab. inż. Regina Paszkiewicz	
Faculty of the course leader:	W12 Faculty of Electronics, Photonics and Microsystems	
Email address of the course leader:	Regina.Paszkiewicz@pwr.edu.pl	
Scientific discipline(s) assigned to the course (doctoral students representing the marked disciplines can participate in the course):	Architecture and urban planning	☐
	Automation, electronic, electrical engineering and space technologies	☒
	Information and communication technology	☐
	Biomedical engineering	☐
	Chemical engineering	☐
	Civil engineering, geodesy and transport	☐
	Materials engineering	☐
	Mechanical engineering	☐
	Environmental engineering, mining, and energy	☐
	Mathematics	☐
	Chemical sciences	☐
	Physical sciences	☐
	Management and quality studies	☐

2. Objectives

Ph D students introduction to the technologies of low-dimensional semiconductor structures (NSP) manufacturing
Getting of Ph D students acquainted with the areas of NSP applications
Getting of Ph D students acquainted with the current state and development trends of the NSP fabrication and applications

3. Content

Detailed information about the course content, including topics and form of classes.

No.	Topic	Number of hours	Form of classes
1	Nanotechnology, definition, classification. Areas of application	2	lecture
2	Miniaturization, scaling, new functional properties of nanostructures. Nanostructures architecture	2	lecture
3	Basics of semiconductor nanostructures manufacturing technology	2	lecture
4	Infrastructure of modern technological laboratory of "clean room" type (purity of gases, water and reagents, security problems)	2	laboratory
5	Lithographic and non-lithographic methods of nanostructures manufacturing, nano-substrates	2	lecture
6	Review of basic technological processes (bulk crystallization, deposition, doping, etching, oxidation, lithography, self-organization and catalysis)	2	lecture
7	Selected methods of photonic crystal fabrication ("micropulling"), epitaxy of low-dimensional layers and structures (techniques: CVD, MOVPE, MBE)	2	lecture
8	Methods of pattern fabrication, limitation of optical lithography (techniques: UV, DUV, EUV)	2	lecture
9	X-ray lithography (LIGA technique), ion-lithography, electron-lithography, sampling methods ("dip-pen", "nanoscraching"), nanoimprint	2	lecture
10	Self-organizing semiconductor structures. Quantum wells, wires, dots: growth, positioning and stability	2	lecture
11	Properties and fabrication of individual nanoparticles: carbon nanotubes, non-diamond, DLC, graphene, organic materials - their application for devices	2	lecture
12	Selected methods of nanostructures properties characterization	2	lecture
13	Examples of nanostructures application in devices (lasers, HEMT transistors, transducers and sensors)	2	lecture
14	Current trends in nanotechnology, new materials (nano-powders, nano-crystals, nano-composites, layered materials, gradient structures) devices (3D transistors, nano-sensors) and nano-tools	2	lecture
15	Summary of the lecture and laboratory visit	2	laboratory

4. Prerequisites

List of prerequisites relating to knowledge, skills and other competences for course participants.

1. Knowledge of solid-state physics
2. Competence to gain complementary areas of knowledge and skills
3. Organizational competences related to the transfer of information

5. Learning outcomes

List of learning outcomes at level 8 of the Polish Qualifications Framework assigned to the course (mark the learning outcomes in the last column).

Symbol	Learning outcome	
	KNOWLEDGE. Doctoral student knows and understands:	
SzD_W3	the main trends in the development of the scientific or artistic disciplines covered in the curricula;	☒
SzD_W4	research methodology;	☒
SzD_W5	the rules for the dissemination of scientific results, including in open access mode;	☐
SzD_W6	the fundamental dilemmas of modern civilization;	☒
SzD_W7	the legal and ethical conditions of scientific activity;	☐
SzD_W8	the economic and other relevant conditions of scientific activity;	☐
SzD_W9	basic principles of knowledge transfer to the economic and social spheres and commercialisation of results of scientific activity and know-how related to these results.	☒
	SKILLS. Doctoral student is able to:	
SzD_U2	use knowledge from different fields of science or art to creatively identify, formulate and innovatively solve complex problems or perform research tasks, in particular: - define the purpose and subject of scientific research, formulate a research hypothesis, - develop research methods, techniques and tools, and use them creatively, - draw conclusions on the basis of scientific research; critically analyse and evaluate the results of scientific research, expertise and other creative work and their contribution to knowledge development; transfer the results of scientific activities to the economic and social spheres;	☒
SzD_U3	communicate on specialised topics to the extent that they enable an active participation in the international scientific community;	☒
SzD_U4	disseminate research results, including in popular forms;	☒
SzD_U5	initiate debates and participate in a scientific discourse;	☒
SzD_U6	be able to speak a foreign language at B2 level of the Common European Framework of Reference for Languages to a level that enables them to participate in the international scientific and professional environment;	☐
SzD_U7	plan and implement an individual or collective research or creative activity, including in an international environment;	☒
SzD_U8	independently plan and act for one's own development and inspire and organize the development of others;	☐
SzD_U9	plan classes or groups of classes and implement them using modern methods and tools.	☐
	SOCIAL COMPETENCES. Doctoral student is ready to:	
SzD_K3	fulfilling the social obligations of researchers and creators, initiate public interest activities, thinking and acting in an entrepreneurial way;	☒
SzD_K4	maintaining and developing the ethos of research and creative environments, including:	☒

	- carrying out scientific activities in an independent manner, - respecting the principle of public ownership of research results, taking into account the principles of intellectual property protection.	

6. Evaluation

Short description of the method(s) used to evaluate the learning outcomes assigned to the course, e.g., exam, test, report, presentation, etc.

Oral answers, test

7. Teaching methods

Short description of the teaching methods used during the course, e.g., multimedia presentation, discussion, literature studies, developing written documents, own work, etc.

Thematic lectures - traditional method,
Thematic laboratory visits - demonstration and discussion,
Own work - preparation for a lecture,
Consultations

8. Literature

List of primary and secondary literature used to prepare the course and including additional knowledge for participants, e.g., books, textbooks, research papers, standards, web pages, etc.

PRIMARY LITERATURE:
[1] Marc J. Madou, Fundamentals of Microfabricationand Nanotechnology, ThirdEdition, BocaRaton, USA, 2011
[2] S. Franssila, Introduction to Microfabrication, John Wiley&Sons Ltd, England, 2004
[3] Kazuaki Suzuki, Microlithography: Science and Technology, Second Edition, CRC Press, Boca Raton, USA, 2007
[4] G. Cao, Y. Wang, Nanostructures and Nanomaterials: Synthesis, Properties, and Applications, Second Edition, World Scientific Publishing Co., Pte. Ltd., Singapore, China, 2011
[5] [Douglas Natelson, Nanostructures and Nanotechnology, Cambridge University Press, 2015
SECONDARY LITERATURE:
[1] Journals: Journal of Nanostructures, Compound Semiconductors, Semiconductor Engineering

9. Other remarks

Additional remarks, comments, (e.g., language of the course)