JAGIELLONIAN UNIVERSITY
IN KRAKÓW

Cutting-edge Techniques for Future Materials

Basic information on the course

Jagiellonian University unit	Doctoral School of Exact and Natural Sciences
Education level	Full-time education programmes in Biophysics, Physics, Chemistry, Biochemistry, biophysics, molecular biology and biotechnology
Number of semesters	1
Language of instruction	English
Education period	**Academic year 2024/2025, 2025/2026** Spring semester 2024/2025, Winter semester 2025/2026, Spring 2025/2026
Course code	**SDSP-33**
Time and Venue	**Tuesday 10:30 am – 12:00 pm**
Forms of verifying learning outcomes	Examination with grade
Number of contact hours	30
Course coordinator	dr hab. Ewelina Lipiec, prof. UJ, dr hab. Marlena Gryl, prof. UJ, dr hab. Jakub Szlachetko, prof. UJ
Course instructor	dr hab. Ewelina Lipiec, prof. UJ, dr hab. Marlena Gryl, prof. UJ, dr hab. Jakub Szlachetko, prof. UJ

Teaching Aims

A1	Detailed studies of the chemical structure, composition and unique properties of future materials are a prevented or largely prohibited due to the limitations of conventional analytical techniques. Low sensitivity and resolution prevent detailed examination of future materials. Local changes in the chemical structure determine the properties and functionality of materials, and their examination requires the use of very sensitive, state-of-the-art techniques. The main goal of the course is to familiarize young scientists with innovative and unique analytical approaches. The proposed online course will provide PhD students with a unique opportunity to expand their knowledge of the most advanced and innovative analytical techniques that push the limits of detection to investigate unknown properties of future materials at the electronic, atomic, molecular and structural levels.
A2	PhD students will learn about principles of experimental techniques, that provide insights into the local chemical structure of future materials. The course focus on selected experimental approaches, including: cryo-electron microscopy, molecular

	nanospectroscopy, single-molecule fluorescence microscopy, electron diffraction, scanning probe microscopy in ultra-high vacuum, nanocrystallography.

Learning outcomes[1]

Knowledge. **Student knows** **and understands:**	**Learning outcomes on level 8 PQF (e.g. P8S_WG, P8S_WK)**
The current role of modern analytical approaches in analysis of future materials	Understanding the complex process of an introduction of the most powerful analytical techniques into investigation of future materials; general and selected specific issues; broad knowledge of research methodology applied in analytical procedures;
Skills. Student can:	**Methods of verifying learning outcomes:**
Define and analyse analytical problems related to an application of comprehensive and complex methodology in investigation into materials of future	Students will prepare a two-page project describing the use of a selected technique in the examination of the sample they are interested in. Coordinators will provide the possibility of consultation with experts/lecturers during the preparation of works. Projects will be evaluated by lecturers. In addition an exam, which involves "the project defense" will be performed.
Social competencies. Student is ready:	**Methods of verifying learning outcomes:**
Critically evaluate achievements within investigation into future materials;	Evaluation of the project, oral exam (in terms of project defense), participation in discussions;

[1] *Please see explanation in section* **LEARNING OUTCOMES ON LEVEL 8 PQF** *on page 4 and 5*.

ECTS – Credits

No of hours needed to complete the course per semester	60
Student's individual workload	30
Total no of contact hours	30
Total no of ECTS	***3***
** teaching hour = 45 minutes*	

Course content

Course content	**Learning outcomes for the course** [2]
Term "future material" encompasses any material anticipated or expected to be developed or become prominent in the future. Such materials possess advanced or novel properties, are more sustainable, or offer advantages over currently available materials in specific applications. This course involves the theoretical introduction, that cover physical and chemical background required to understand the working principles of the selected analytical approaches: atomic force microscopy, on-surface synthesis of higher acenes and nanographenes, light scattering from solutions and dispersion, solid-state nuclear magnetic resonance (NMR) spectroscopy, Raman spectroscopy, micro-CT Scan, X-ray absorption spectroscopy (XAS), angle-resolved photoemission spectroscopy (ARPES), photoelectron emission microscopy (PEEM), cryo-EM, Flow cytometry, positron anihilationm adhesion, friction and wear of materials, infrared nanospectroscopy and nanocrystallography;	Knowledge of physical and chemical background required to understand the working principles of the selected analytical approaches;

[2] *Please see explanation in section* **LEARNING OUTCOMES ON LEVEL 8 PQF** *on page 4 and 5*.

Demonstrating of the infrastructure, required for the implementation of the above motioned techniques, presentation of data acquisition process, sample preparation methods and analysis, and also an interpretation of the obtained experimental data;	Knowledge of practical principles regarding each analytical technique introduced during the lecture, including: sample preparation procedures, data acquisition, advanced data analysis and interpretation of the results. Critical evaluation of analytical techniques, that involves the most innovative experimental approaches in deep investigation into chemical structure, composition and physical properties of various materials;
Up-dated each year presentation of the most important achievements and the latest applications of the selected experimental/analytical techniques;	General knowledge of recent and the most significant achievements in experimental investigation into future materials;

Additional information

Teaching methods	Each individual lecture will be divided into three parts: 1. "The physics/chemistry behind" - specially prepared recordings and literature, including a theoretical introduction to each technique, physical/chemical basics necessary to understand a given experimental/analytical approach, (approx. 30 min) 2. "Virtual visit in the lab" - specially prepared recordings or on-line transmission (depending on the lecturer's preferences) aimed at demonstrating the infrastructure, presentation of data acquisition process, sample preparation methods and analysis and interpretation of the received data. 3. "Recent state-of-art and applications" - a remote, continuously updated part of the lecture (live) presenting the most important achievements and the latest applications of the selected experimental/analytical technique. Lectures will be given by the experts in each presented field including: Prof. Marek Szymoński, *Jagiellonian University*, Prof. Brian Rodriguez, *University College Dublin*, Prof. Szymon Godlewski, *Jagiellonian University*, Prof. Vladimir Aseyev, *Univeristy of Helsinki*, Prof. Sami

	Hietala, *Univeristy of Helsinki,* Prof. Javier Sánchez Benítez, *University Complutense of Madrid, Prof.* Margarita Chevalier del Río, *Complutense of Madrid,* Prof. Marco Giorgetti, *University of Bologna,* Prof. Arantzazu Mascaraque *University Complutense of Madrid*, Prof. Dimitri Scholz (*University College Dublin,* Prof. Alfonso Fernández, *University College Dublin,* Prof. Filip Tuomisto, *University of Helsinki,* Prof. Vasileios Koutsos, Prof. Tomasz Wróbel, *Solaris Synchrotron*, Prof. Marcin Kozieł *Jagiellonian University*, Prof. Marcin Oszajca, *Jagiellonian University*.
Forms of attaining ECTS	Oral exam
Conditions of attaining ECTS	Positive result of the evaluation of the project and the oral exam, participation in discussions
Entry requirements (if any)	Not applicable

Resources

Literature:

Mandatory	***Additional***
The lecture will be based on the latest literature, which will be updated each year	The lecture will be based on the latest literature, which will be updated each year

LEARNING OUTCOMES ON LEVEL 8 PQF

Through education in a doctoral school, doctoral students acquire learning outcomes for qualifications at level 8 of the Polish Qualifications Framework.

The learning outcomes are defined in terms of:

- **knowledge**
- **skills**
- **social competences.**

Legend:

P8S_WG (knows and understands)

- to the extent allowing to revise existing paradigms, the world-wide body of knowledge covering theoretical foundations and general and selected specific issues – appropriate to the scientific or artistic discipline,
- major trends in the development of the scientific or artistic disciplines in which the training is given,
- research methodology,
- the rules for dissemination of scientific results, including through open access,

P8S_WK (knows and understands)

- fundamental dilemmas of modern civilisation
- economic, legal, ethical, and other relevant determinants of scientific activity
- the basic principles for the transfer of knowledge to the economic and social spheres and for the commercialisation of the results of scientific activities and of the know-how related to these results,

P8S_UW (can)

- use knowledge from different scientific disciplines or the arts to creatively identify, formulate and innovatively solve complex problems or perform tasks of a research nature, in particular:
- define the purpose and object of scientific research, formulate a research hypothesis,
- develop research methods, techniques and tools and apply them creatively,
- make inferences from scientific findings,
- critically analyse and evaluate the results of scientific research, expert activities and other works of a creative nature and their contribution to the advancement of knowledge,
- transfer the results of scientific activities to the economic and social spheres,

P8S_UK (can)

- communicate on specialist subjects to the extent necessary for active participation in the international scientific community,
- disseminate the results of scientific activities, including in popular forms,
- initiate debate,
- participate in scientific discourse,
- use a foreign language at B2 level of the Common European Framework of Reference for Languages to the extent necessary for participation in an international scientific and professional environment,

P8S_UO (can)

- plan and carry out individual and team research or creative projects, including in an international environment,

P8S_UU (can)

- independently plan and act for their own development and inspire and organise the development of others,
- plan and deliver a class or group of classes using modern methods and tools,

P8S_KK (is ready to)

- critically evaluate achievements within a scientific or artistic discipline,
- critically appraise one's own contribution to the development of that scientific or artistic discipline,
- recognise the importance of knowledge in solving cognitive and practical problems,

P8S_KO (is ready to)

- fulfil the social obligations of researchers and authors,
- initiate actions in the public interest,

- think and act entrepreneurially,

P8S_KR (is ready to)

- uphold and develop the ethos of the research and creative community, including: - conducting scientific activity in an independent manner,
- respect the principle of public ownership of scientific results, taking into account the principles of protection of intellectual property.