

PHD STUDIES COURSE UNIT DESCRIPTION

Name of subject	Field of science, code	Faculty / Center	Department
Nanomaterials Research Methods	Chemistry N 003	ChGF	Physical Chemistry
Student's workload	Credits	Student's workload	Credits
Lectures		Consultations	3
Independent study	7	Seminars	

Course annotation

The "Nanomaterials Research Methods" course is designed to equip PhD students with the essential theoretical knowledge necessary to conduct advanced and complex research in nanomaterials science. The course will cover a broad range of techniques and approaches used in the synthesis, characterization, and application of nanomaterials. Students will learn how to work with cutting-edge nanomaterials research methods, critically analyze experimental data, and effectively communicate their research findings. The course will foster both general and subject-specific competencies required for innovative work in nanotechnology and related fields. The course is intended to prepare PhD students for independent research projects, collaborations across multidisciplinary fields, and future contributions to the scientific community.

Topics Covered:

- 1. Characterization Techniques: Microscopy**
Scanning electron microscopy (SEM), transmission electron microscopy (TEM), atomic force microscopy (AFM), and other advanced imaging techniques.
- 2. Characterization Techniques: Spectroscopy**
Raman spectroscopy, X-ray photoelectron spectroscopy (XPS), and Fourier-transform infrared spectroscopy (FTIR) for material analysis.
- 3. Nanomaterial Surface Functionalization and Research Methods**
Methods to modify and functionalize nanomaterials for specific applications, including bioconjugation and ligand attachment.
- 4. Mechanical Properties of Nanomaterials and Research Methods**
Testing and evaluation of mechanical properties like elasticity, hardness, and fracture strength at the nanoscale.
- 5. Optical Properties of Nanomaterials and Research Methods**
Exploration of plasmonics, quantum dots, and other phenomena associated with the optical behavior of nanomaterials.
- 6. Electrical and Magnetic Properties of Nanomaterials and Research Methods**
Conductivity, superconductivity, and magnetism in nanostructured materials and their potential applications.
- 7. Nanomaterials in Medicine and Biotechnology and Research Methods**
Application of nanomaterials in drug delivery systems, diagnostic tools, and tissue engineering.
- 8. Environmental Impacts of Nanomaterials and Research Methods**
Analysis of the effects of nanomaterials on the environment, including toxicity and ecological risks.
- 9. Computational Methods, AI in Nanomaterials Research**
Simulation techniques and computational modeling used to predict nanomaterial behavior and optimize their properties.
- 10. Nanomaterials for Energy Applications and Research Methods**
Role of nanomaterials in renewable energy, including applications in batteries, fuel cells, and solar cells.
- 11. Nanomaterials in Sensors and Detectors and Research Methods**
Design and fabrication of nanosensors for detecting chemical, biological, and environmental changes.
- 12. Research Ethics and Safety in Nanotechnology**
Ethical considerations, safety protocols, and regulations associated with conducting research in nanomaterials and nanotechnology.
- 13. Quantum Effects in Nanomaterials and Research Methods**
Investigation of quantum confinement, tunneling, and size-dependent electronic properties in nanostructures like quantum dots and nanowires.

14. **Nanomaterials in Catalysis and Research Methods**
The role of nanomaterials as catalysts, including heterogeneous catalysis, photocatalysis, and the design of nanocatalysts for specific chemical reactions.
15. **Nanomaterials for Photonic Applications and Research Methods**
Study of nanostructures used in photonic devices such as lasers, waveguides, and optical fibers, with a focus on manipulating light-matter interactions at the nanoscale.
16. **Hybrid Nanomaterials and their Research Methods: Composites and Heterostructures**
Design, fabrication, and applications of hybrid nanomaterials combining multiple phases or materials, such as graphene-based composites or core-shell nanoparticles.
17. **Nanomaterials in Advanced Manufacturing and 3D Printing and Research Methods**
Exploration of additive manufacturing techniques using nanomaterials, and their role in producing functional, complex structures at the micro- and nanoscale.
18. **Multifunctional Nanomaterials and their Research Methods**
Development of nanomaterials with multifunctional capabilities, such as combining optical, magnetic, and catalytic properties in a single system for advanced applications.
19. **Nanoelectronics and Nanoscale Devices and their Research Methods**
Study of the design and fabrication of nanoscale electronic devices, such as transistors, memory devices, and molecular electronics, exploring their potential beyond traditional semiconductor technologies.
20. **Nanotoxicology and Risk Assessment and Research Methods**
Detailed evaluation of the biological interactions, toxicological effects, and risk assessment of engineered nanomaterials in living organisms and ecosystems.
21. **Thermodynamics and Kinetics in Nanomaterials and Research Methods**
Application of thermodynamic principles to understand phase transitions, stability, and the kinetic pathways of nanomaterial formation and reactions.
22. **Advanced In Situ Characterization Techniques and Research Methods**
Techniques such as in situ TEM and X-ray diffraction (XRD) to monitor real-time changes in nanomaterials under various conditions (e.g., high temperature, mechanical stress, or during reactions).
23. **Sustainability aspects in nanomaterials research.**

Reading list

1. NANOSTRUCTURES AND NANOMATERIALS: SYNTHESIS, PROPERTIES AND APPLICATIONS. Illustrated Edition, by Guozhong Cao. Publisher : Imperial College Press; Illustrated edition (April 12, 2004)
2. Advanced Materials Characterization Techniques: Material characterization – Electronic & Optical properties, by Dr. Subhamoy Singha Roy, by Guozhong Cao. Publisher : LAP LAMBERT Academic Publishing (October 13, 2022). Publisher : Springer; 2024th edition (December 19, 2024)
3. Characterization of Nanoparticles Intended for Drug Delivery (Methods in Molecular Biology Book 2789) 3rd Edition, by Jeffrey D. Clogston (Editor), Rachael M. Crist (Editor), Marina A. Dobrovolskaia (Editor), Stephan T. Stern (Editor). Publisher : Humana; 3rd edition (March 20, 2024)
4. Nanomaterials for Advanced Technologies, by Jitendra Kumar Katiyar (Editor), Vinay Panwar (Editor), Neha Ahlawat (Editor). Publisher: Springer (May 24, 2022)

The names of consulting teachers	Science degree	Main scientific works published in a scientific field in last 5 year period
Assoc. Prof. Urte Prentice	PhD	Kaspote, G.; Ramanavicius, A.; Prentice, U. Molecular Imprinting Technology for Advanced Delivery of Essential Oils. Polymers, 2024,16, 244. https://doi.org/10.3390/polym16172441 Sarvutiene. J.; Prentice, U.; Ramanavicius, S.; Ramanavicius, A. Molecular imprinting technology for biomedical applications, Biotechnology Advances, 2024, 17, 108318. https://doi.org/10.1016/j.biotechadv.2024.108318 Dronina, J., Samukaite-Bubniene, U. & Ramanavicius, A. Towards application of CRISPR-Cas12a in the design of modern viral DNA detection tools (Review). J Nanobiotechnol, 2022, 20, 41. https://doi.org/10.1186/s12951-022-01246-7

		Samukaite-Bubniene, U.; Valiūnienė, A.; Bucinskas, V.; Genys, P.; Ratautaite, V.; Ramanaviciene, A.; Aksun, E.; Tereshchenko, A.; Zeybek, B.; Ramanavicius, A., Towards supercapacitors: Cyclic voltammetry and fast Fourier transform electrochemical impedance spectroscopy based evaluation of polypyrrole electrochemically deposited on the pencil graphite electrode, Colloids and Surfaces A: Physicochemical and Engineering Aspects, 2021, 610, 125750. https://doi.org/10.1016/j.colsurfa.2020.125750
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Certified during Doctoral Committee session on March 3 rd , 2025. Protocol No. 15600-KT-79.
Committee Chairman prof. habil. dr. Audrius Padarauskas.