UČNI NAČRT PREDMETA / COURSE SYLLABUS	
Predmet:	Mikroskopija nanomaterialov
Course title:	Microscopy of Nanomaterials

Študijski program in stopnja Study programme and level	Študijska smer Study field	Letnik Academic year	Semester Semester
Nanoznanosti in nanotehnologije, 3. stopnja	/	1	1
Nanosciences and Nanotechnologies, 3rd cycle	/	1	1

Vrsta predmeta / Course type	Izbirni / Elective
Univerzitetna koda predmeta / University course code:	NANO3-812

Predavanja Lectures	Seminar Seminar	Vaje Tutorial	Klinične vaje work	Druge oblike študija	Samost. delo Individ. work	ECTS
15	**15**			**15**	**105**	**5**

**Navedena porazdelitev ur velja, če je vpisanih vsaj 15 študentov. Drugače se obseg izvedbe kontaktnih ur sorazmerno zmanjša in prenese v samostojno delo. / This distribution of hours is valid if at least 15 students are enrolled. Otherwise the contact hours are linearly reduced and transfered to individual work.*

Nosilec predmeta / Lecturer:		Prof. dr. Maja Remškar
Jeziki / Languages:	**Predavanja / Lectures:**	Slovenščina, angleščina / Slovenian, English
	Vaje / Tutorial:	

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	**Prerequisits:**
Zaključena izobrazba druge stopnje ali univerzitetna izobrazba s področja naravoslovja ali tehnologije.	Completed second level education or university education from natural sciences or technology.

Vsebina:	**Content (Syllabus outline):**
Morfološke in kristalografske lastnosti organskih in anorganskih nanodelcev: vlaken, iglic, kroglastih nanodelcev, ki so vsaj v eni smeri manjši od 100 nm. Metode za zbiranje in sortiranje nanodelcev po velikosti in masi v tekočih in plinastih medijih (večstopenjski impaktorji, elektrostatična klasifikacija). Specifične fizikalne in kemijske lastnosti nizkodimenzionalnih sistemov: samourejanje, aglomeriranje, rekonstrukcije, relaksacije, fazni prehodi, kvantni efekti. Sinteza ekvivalentnih nanodelcev v laboratorijskih pogojih v zadostnih količinah za uporabo makroskopskih karakterizacijskih metod. Detekcija kemijske	Morphological and crystallographic properties of organic and inorganic nanoparts: fibres, needles, spherical nanoparts which are smaller than 100 nm at least in one direction. Methods of collecting and sorting of nanoparts by size and mass in crystal and gaseous media (multistage impactors, electrostatic classification). Specific physical and chemical properties of low-dimensional systems. Self-arrangement, agglomeration, reconstructions, relaxations, phase transfers, quantum effects. Synthesis of equivalent nanoparticles in laboratory conditions in adequate quantities for use of macroscopic characterization methods. Detection of chemical activity in reducing dimensions of

aktivnosti pri zmanjševanju dimenzij nanodelcev z ozirom na biokompatibilnost oz. toksičnost. Metode za karakterizacijo nanomaterialov: visokoločljivostna presevna elektronska mikroskopija, vrstična elektronska mikroskopija, vrstična tunelska mikroskopija in spektroskopija, mikroskopija na atomsko silo, spektroskopija elektronskih izgub energije. Pregled osnovnih metod za kontrolo namenske proizvodnje oz. nenamenske emisije nanodelcev v delovno in splošno okolje. Obravnavani primeri bodo prilagojeni ciljem in vsebini raziskovalnega projekta podiplomca.	nanoparticles regarding biocompatibility and/or toxicity. Methods of characterization of nanomaterials: high-resolution transmission electronic microscopy, scanning electronic microscopy, scanning tunnel microscopy and spectroscopy, atomic force microscopy, spectroscopy of electronic energy losses. Overview of the basic methods for monitoring of intentional generation or accidental emission of nanoparticles into the occupational and general environment. The cases under consideration will be adapted to the objectives and content of the postgraduate student's research project.

Temeljni literatura in viri / Readings:

- »Molecular- and Nano-Tubes«, O. Hayden and K. Nielsch (editors), Springer, 2011.
  S.C. Wang and R.C. Flagan, »Scanning electrical mobility spectrometer«, Aerosol Sci. And Tech. 13, 230-240, 1990.
- »Nanomaterials: Inorganic and Bioinorganic Perspectives«, C.M. Lukehart and R.A. Scott (editors) John Wiley and Sons Ltd., 2008.
- C.J. Chen: »Introduction to scanning tunnelling microscopy« (Oxford Series in Optical and Imaging Sciences, 4), Oxford University Press, 1993.
- D.B. Williams, C.B. Carter: »Transmission electron microscopy: A textbook for material science«, Kluwer Academic/Plenum Publishers, 1997

Cilji in kompetence:	**Objectives and competences:**
Študentje spoznajo specifične fizikalne in kemijske zakonitosti, povezane z nanometrskimi dimenzijami, metode za merjenje nanodelcev v tekočih in plinastih medijih ter mikroskopske metode za njihovo morfološko, fizikalno in kemijsko identifikacijo.	The students learn specific physical and chemical laws related to nanometric dimensions, methods of measurement of nanoparticles in liquid and gaseous mediums and microscopic methods for their morphological, physical and chemical identification.

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanje in razumevanje: • Razumevanje sodobnih mikroskopskih metod pri karakterizaciji strukture nanomaterialov Splošne sposobnosti: • obvladanje raziskovalnih metod, postopkov in procesov, • razvoj kritične in samokritične presoje, • razvoj komunikacijskih sposobnosti in spretnosti, posebej komunikacije v mednarodnem okolju, • sodelovanje, delo v skupini (v mednarodnem okolju).	Knowledge and understanding: • The student will understand modern microscopic methods for the characterization of the structure of nanomaterials General learning outcomes: • the students will master research methods, procedures, and processes, • the students will develop critical thinking, • the students will develop communication skills to present research achievements in the international environment, • cooperation, work in teams (in international environment).

Predmetne sposobnosti:	Course-specific learning outcomes:
• Predmet pripravlja študente za uporabo znanja s področja sodobnih mikroskopskih metod pri karakterizaciji strukture nanomaterialov.	• This course prepares students to apply knowledge of modern microscopic methods for the characterization of the structure of nanomaterials.

Metode poučevanja in učenja:	**Learning and teaching methods:**
• predavanja • seminarji • konzultacije	• lectures • seminar work • consultations

Načini ocenjevanja:	Delež (v %) / Weight (in %)	**Assessment:**
• seminar	50 %	• seminar
• ustni izpit	50 %	• oral exam

Reference nosilca / Lecturer's references:

- REMŠKAR, Maja, TAVČAR, Gašper, ŠKAPIN, Srečo D. Sparklers as a nanohazard : size distribution measurements of the nanoparticles released from sparklers. *Air Quality, Atmosphere & Health*, ISSN 1873-9318, 2015, vol. 8, no. 2, str. 205-211
- TOMALA, Agniezka, RODRÍGUEZ RIPOLL, Manel, GABLER, C., REMŠKAR, Maja, KALIN, Mitjan. Interactions between MoS2 nanotubes and conventional additives in model oils. *Tribology International*, ISSN 0301-679X. [Print ed.], June 2017, vol. 110, str. 140-150
- FATHIPOUR, S., REMŠKAR, Maja, VARLEC, Ana, et al. Synthesized multiwall MoS2 nanotube and nanoribbon field-effect transistors. Applied Physics Letters, ISSN 0003-6951. [Print ed.], 2015, vol. 106, no. 2, str. 022114 -1-022114 -4, doi: 10.1063/1.4906066
- REMŠKAR, Maja, ISKRA, Ivan, JELENC, Janez, ŠKAPIN, Srečo D., VIŠIĆ, Bojana, VARLEC, Ana, KRŽAN, Andrej. A novel structure of polyvinylidene fluoride (PVDF) stabilized by MoS2 nanotubes. Soft Matter, ISSN 1744-683X, 2013, vol. 9, no. 36, str. 8647-8653, doi: 10.1039/c3sm51279g
- REMŠKAR, Maja, JELENC, Janez. Influence of surface defects on superlattice patterns in graphene on graphite. *Surface science*, ISSN 0039-6028. [Print ed.], vol. 651, str. 51-56