UČNI NAČRT PREDMETA / COURSE SYLLABUS	
Predmet:	Sinteza nanomaterialov
Course title:	Synthesis 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 Nanotechnologijes, 3rd cycle	/	1	1

Vrsta predmeta / Course type Izbirni / Elective

Univerzitetna koda predmeta / University course code: NANO3-833

Predavanja Lectures	Seminar Seminar	Vaje Tutorial	Klinične vaje work	Druge oblike študija	Samost. delo Individ. work	ECTS
30	**30**			**30**	**210**	**10**

**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. Barbara Malič
Doc. dr. Tadej Rojac
Doc. dr. Miha Čekada

Jeziki / Languages:	
Predavanja / Lectures:	Slovenski, angleški / Slovenian, English
Vaje / Tutorial:	-

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:

Zaključen študij druge stopnje naravoslovne ali tehniške smeri ali zaključen študij drugih smeri z dokazanim poznavanjem osnov področja predmeta (pisna dokazila, pogovor).

Prerequisits:

Completed second level studies in natural sciences or engineering or completed second level studies in other fields with proven knowledge of fundamentals in the field of this course (certificates, interview).

Vsebina:

Splošno o nanomaterialih:
- razmerje površina / volumen,
- termodinamske osnove,
- skupine nanomaterialov: nanodelci, nanovlakna, plasti, (aero-)geli, nanostrukture,
- metode sinteze.

Sinteza nanodelcev:
- termodinamske osnove nukleacije nanodelcev,
- homo- / heterogena nukleacija,
- kinetika rasti delcev,
- problem aglomeracije, stabilizacija delcev,
- pregled kemijskih in fizikalnih metod sinteze nanodelcev.

Priprava plasti iz parne faze:

Content (Syllabus outline):

General introduction:
- surface /volume ratio,
- thermodynimcs,
- grouping of nanomaterials: particles, nanofibers, films, (aero-)gels, nanostructures,
- synthetic approaches (top-down, bottom-up).

Synthesis of nanoparticles:
- thermodynamics of nucleation,
- homo- / heterogeneous nucleation,
- growth of nanoparticles, kinetics,
- agglomeracije, stabilization of particles,
- chemical and physical methods of synthesis of particles.

• vakuum, vakuumska tehnologija • podlage – površinska energija • nukleacija, epitaksija, mikrostruktura plasti, • pregled in primerjava metod. Priprava plasti iz raztopin: • sinteza plasti iz raztopin (sol-gel), • Langmuir-Blodgett, • nukleacija in rast plasti, • pregled in primerjava metod. Kserogeli, aerogeli. Nanostrukture: fizikalne in kemijske metode oblikovanja. Metode karakterizacije nanomaterialov.	Deposition of thin films from vapour phase: • vacuum science and technology • substrates, surface energy, types of growth from vapour phase • nucleation, epitaxy, microstructure, • methods of vapour deposition, comparison. Solution deposition of thin films: • sol-gel, chemical solution deposition • substrates, nucleation layers • nucleation, crystallization, evolution of microstructure • Langmuir-Blodgett, • Methods, equipment Xerogels, aerogels. Nanostructures: physical, chemical methods. Methods of characterization of nanomaterials.

Temeljni literatura in viri / Readings:

G. Cao, Nanostructures and Nanomaterials, Imperial College Press, London, 2004.

D. Mitzi (Ed.), Solution Processing of Inorganic Materials, Wiley, Hoboken, 2009.

T. Schneller, R. Waser, M. Kosec, D. Payne (Eds.), Chemical solution deposition of functional oxide thin films, Springer, Wien, 2013.

S.D.Hoath (ed.), Fundamentals of Inkjet Printing, The Sicence of Inkjet and Droplets, Wiley, Weinheim, 2016.

Ciljani izbor in razprava o aktualnih znanstvenih objavah, predvsem v revijah Science, Nature (Nature Nanotechnology, Nature Materials), Advanced Functional Materials, Chemistry of Materials, ACS Nano / Targeted selection and discussion of scientific publications, particularly from Science, Nature (Nature Nanotechnology, Nature Materials), Advanced Functional Materials, Chemistry of Materials, ACS Nano

Cilji in kompetence:	**Objectives and competences:**
Cilj predmeta je seznaniti študente s posebnimi lastnostmi nanomaterialov (nanodelci, nanovlakna, plasti, (aero-)geli, nanostrukture) in z metodami sinteze nanomaterialov. Študent bo znal izbrati primerno metodo sinteze izbranega nanomateriala, poznal bo eksperimentalne omejitve ter prednosti oziroma slabosti posamezne metode. Cilj se navezuje na kompetence: • obvladovanje metod in tehnik sinteze nanomaterialov, • sposobnost za samostojno in skupinsko raziskovalno in razvojno delo, • sposobnost uporabe znanja v praksi in • delno tudi razvoj integralnega načina mišljenja	The objective of the course is to introduce to students special properties of nanomaterials (nanoparticles, nanofibers, films, (aero-)gels, nanostructures) and with methods of their synthesis. The student will be able to select a suitable method of synthesis of a given nanomaterial, he will recognize experimental limitations, and advantages / disadvantages of a selected method. This objective is related to competences: • mastering of methods and techniques of synthesis of nanomaterials, • ability to carry out independent as well as team R&D work, • ability to use the knowledge in practice,

ter sposobnost za komunikacijo s strokovnjaki drugih disciplin in področij.	• and partially also to the development of an integral way of thinking and the ability to communicate with experts from other disciplines and fields.

Predvideni študijski rezultati:	**Intended learning outcomes:**
Študent bo na osnovi pridobljenega znanja: • obvladal kriterije primerjave različnih skupin nanomaterialov • izbral primerno metodo sinteze izbranega nanomateriala • napovedal rezultat izbrane sinteze nanomateriala • ocenil prednosti in slabosti posamezne metode sinteze • napovedal eksperimentalne omejitve posamezne metode sinteze • izbral primerno metodo karakterizacije reakcijskega produkta • znal interpretirati rezultate analiz • vzpostavil sposobnost komunikacije v angleškem jeziku na področju sinteze nanomaterialov	The student will: • Master the criteria of comparison of different groups of nanomaterials • Select a suitable method of synthesis of a given nanomaterial • Forecast the result of a selected synthesis • Judge the advantages / disadvantages of a given method • Forecast experimental limitations • Select a suitable method of characterization of reaction products • Interpret the results of the analysis • Establish the ability to communicate in English in the field of synthesis of nanomaterials

Metode poučevanja in učenja:	**Learning and teaching methods:**
Interaktivna predavanja Seminar Delo v laboratoriju Konzultacije	Interactive lectures Seminar Work in laboratory Consultations

Načini ocenjevanja:	Delež (v %) / Weight (in %)	**Assessment:**
Seminarska naloga.	30 %	Seminar work.
Zagovor seminarske naloge, pri katerem študent dokaže osvojitev vseh študijskih izidov z vsaj po enim konkretnim primerom.	30 %	Defense of the seminar work where the student demonstrates the achievement of all learning outcomes with at least one specific case for each outcome.
Ustni izpit.	40 %	Oral examination.

Reference nosilca / Lecturer's references:

VOJISAVLJEVIĆ, Katarina, WICKER, Susanne, CAN, Inci, BENČAN, Andreja, BARSAN, Nicolae, MALIČ, Barbara. Nanocrystalline cobalt-oxide powders by solution-combustion synthesis and their application in chemical sensors. *Advanced powder technology*, ISSN 0921-8831. [Print ed.], 2017, vol. 28, no. 4, str. 1118-1128, doi: 10.1016/j.apt.2016.10.029. [COBISS.SI-ID 30119719],

MATAVŽ, Aleksander, BOBNAR, Vid, MALIČ, Barbara. Tailoring ink-substrate interactions via thin polymeric layers for high-resolution printing. *Langmuir*, ISSN 0743-7463, 2017, vol. 33, no. 43, str. 11893-11900, doi: 10.1021/acs.langmuir.7b02181. [COBISS.SI-ID 30841383],

PEČNIK, Tanja, GLINŠEK, Sebastjan, KMET, Brigita, MALIČ, Barbara. Combined effects of thickness, grain size and residual stress on the dielectric properties of Ba0.5Sr0.5TiO3Ba0.5Sr0.5TiO3 thin films. *Journal of alloys and compounds*, ISSN 0925-8388. [Print ed.], 2015, vol. 646, str. 766-772,

doi: 10.1016/j.jallcom.2015.06.192. [COBISS.SI-ID 28751655],

ROJAC, Tadej, BENČAN, Andreja, DRAŽIĆ, Goran, SAKAMOTO, Naonori, URŠIČ, Hana, JANČAR, Boštjan, TAVČAR, Gašper, MAKAROVIČ, Maja, WALKER, Julian, MALIČ, Barbara, DAMJANOVIĆ, Dragan. Domain-wall conduction in ferroelectric BiFeO3BiFeO3 controlled by accumulation of charged defects. *Nature materials*, ISSN 1476-1122, 2017, vol. 16, no. 3, str. 322-327, doi: 10.1038/nmat4799. [COBISS.SI-ID 29936679],

DRNOVŠEK, Aljaž, PANJAN, Peter, PANJAN, Matjaž, ČEKADA, Miha. The influence of growth defects in sputter-deposited TiAlN hard coatings on their tribological behavior. *Surface & coatings technology*, ISSN 0257-8972. [Print ed.], 2016, vol. 288, str. 171-178, doi: 10.1016/j.surfcoat.2016.01.021. [COBISS.SI-ID 29221159].