STRUKTURNA KARAKTERIZACIJA MATERIALOV ZA ENERGETIKO

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Strukturna karakterizacija materialov za energetiko
Course title:	Structural Characterization of Energy Materials
Članica nosilka/UL Member:	UL FKKT

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Kemija, druga stopnja, magistrski (od študijskega leta 2025/2026 dalje)	Materiali za shranjevanje in pretvorbo energije (smer)	2. letnik	1. semester	obvezni

Univerzitetna koda predmeta/University course code:	0185890
Koda učne enote na članici/UL Member course code:	TU16UN

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
20	10	20 SV			50	4

Nosilec predmeta/Lecturer:	prof. dr. Anton Meden
Vrsta predmeta/Course type:	obvezni/Mandatory
Jeziki/Languages:	Predavanja/Lectures: Angleščina Vaje/Tutorial: Angleščina

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	Prerequisites:
Vpis v 2. letnik MŠP Materiali za shranjevanje in pretvorbo energije. Predmet lahko izberejo tudi tuji študenti na mednarodni izmenjavi na UL, ki morajo imeti podpisan učni sporazum (LA) med UL FKKT in drugimi tujimi izobraževalnimi ustanovami.	Enrolment in the 2nd year of USP "Materials for Energy Storage and Conversion" (MESC). The subject can be attended by international exchange students that have a signed learning agreement between UL FKKT and another foreign educational institution.

Vsebina:	Content (Syllabus outline):
Kristalne strukture: amorfno in kristalinično stanje, primeri struktur energetskih materialov. **Simetrija:** ugotavljanje simetrije na primerih struktur, simetrijski elementi, točkovne skupine, prostorske skupine, kristalni sistemi, osnovna celica, kristalne mreže.Vpliv simetrije na fizikalne lastnosti energetskih materialov. **Difrakcija:** radiacija in njena interakcija s kristali, Braggov zakon, difrakcija na monkristalu in prahu.	**Crystal structures:** amorphous and crystalline state, examples of energy materials structures. **Symmetry:** exploring symmetry in the example structures, symmetry elements, point groups, space groups, crystal systems, unit cell, crystal lattices. The effect of symmetry on the physical properties of energy materials. **Diffraction:** radiation and its interaction with crystals, Bragg law, single crystal and powder diffraction.

Identifikacija in kvantifikacija faz: osnove metode, uporaba obstoječega znanja (zbirke podatkov), primer iskalnega programa, osnove in primeri kvantitativne fazne analize s poudarkom na energetskih materialih. **Osnove reševanja struktur:** difraktogram in strukturna informacija, metode z monokristali, praškovne metode, koraki določanja strukture iz praškovnih difrakcijskih podatkov. **Rietveldovo prilagajanje:** informacijska vsebnost praškovnega difraktograma, možne uporabe RP s poudarkom na energetskih materialih. **Osnove fizike trdnega stanja in teoretske kemije:** zveza med lastnostmi na atomski skali in makroskopskimi lastnostmi z nekaj primeri energetskih materialov.	**Phase identification and quantification:** origin of the method, use of existing knowledge (databases) example of a search-match program, basics and examples of quantitative phase analysis with a focus on energy materials. **Crystal Structure solution-basics:** diffraction pattern and structural information, singe crystal methods, powder methods, steps of structure determination from powder diffraction data. **Rietveld refinement:** information content in the powder pattern, possible uses of RR with a focus on energy materials. **Basics in Solid State Physics and Theoretical Chemistry:** relation between atomic-scale properties and large-scale properties with some examples of energy materials.

Temeljna literatura in viri/Readings:

V. K. Pecharsky and P. Z. Zavalij: Fundamentals of Powder Diffracton and Structural Characterization of Materials, Second edition, Springer, ISBN 978-0-387-09578-3, e-ISBN 978-0-387-09579-0, New York, USA, 2009.

Cilji in kompetence:	**Objectives and competences:**
Cilji: Razumevanje strukturnih principov v trdninah, ki se uporabljajo kot energetski materiali, njihove lastnosti in metode njihovega proučevanja, temelječe na difrakciji. **Kompetence:** Uporaba osnovnih tehnik karakterizacije, temelječih na praškovni difrakciji.	**Objectives:** Understanding of structural principles of solids used as energy materials, their properties and diffraction-based methods of studying thereof. **Competences:** Use of basic powder-diffraction-based characterization techniques.

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanje in razumevanje Poznavanje temeljnih strukturnih principov v anorganskih in organskih trdninah ter razumevanje le-teh. Usvajanje povezave med kristalno strukturo in njeno difrakcijsko sliko ter načinom njene uporabe. Uporaba Uporaba praškovne difrakcije za temeljno karakterizacijo energetskih materialov. Uporaba orodij in podatkov iz kristalografskih podatkovnih zbirk. Refleksija Sposobnost kritičnega pogleda na metode in rezultate praškovne difrakcije v širšem kontekstu karakterizacije materialov. Prenosljive spretnosti Praksa v reševanju problemov. Veščine dela z računalniki. Uporaba zbirk podatkov in branja znanstvenih člankov.	Knowledge and Comprehension Knowledge of the basic structural principles of inorganic and organic solids and understanding of structural principles. Comprehension of connection between crystal structure and its diffraction image and pathways of using thereof. Application Use of powder diffraction for basic characterization of energy materials. The application of tools and data from crystallographic databases. Analysis Capability of critical view of powder diffraction methods and their results in a broader scope of materials characterization. Skill-transference Ability Practice in problem-solving. Students get skills in working with computers. The application of databases and reading scientific papers.

Metode poučevanja in učenja:	**Learning and teaching methods:**
Predavanja, vodene vaje ob uporabi računalniških programov, vaje v majhnih skupinah in individualno.	Lectures, tutorials using computer programs, small group and individual exercises.

Načini ocenjevanja: **Delež/Weight** **Assessment:**

Ustni izpit, ki vključuje reševanje praktičnega problema	100,00 %	Oral exam including solution of a practical problem

Ocenjevalna lestvica:	**Grading system:**
5 - 10, pri čemer velja, da je pozitivna ocena od 6 - 10	5 - 10, a student passes the exam if he is graded from 6 to 10

Reference nosilca/Lecturer's references:

1.) STARE, Katarina, STARE, Jernej, ŠKAPIN, Srečo D., SPREITZER, Matjaž, MEDEN, Anton. Structure determination and analysis of the ceramic material La0.987Ti1.627Nb3.307O13 by synchrotron and neutron powder diffraction and DFT calculations. Crystals. Mar. 2023, vol. 13, iss. 3, [article no.] 439, str. 1-17, ilustr. ISSN 2073-4352. DOI: 10.3390/cryst13030439.

2.) KAMŠEK, Ana Rebeka, MEDEN, Anton, ARČON, Iztok, JOVANOVIČ, Primož, ŠALA, Martin, RUIZ-ZEPEDA, Francisco, DRAŽIĆ, Goran, GABERŠČEK, Miran, BELE, Marjan, HODNIK, Nejc. Periodic anti-phase boundaries and crystal superstructures in PtCu3 nanoparticles as fuel cell electrocatalysts. Materials today nano. Aug. 2023, vol. 23, [article no.] 100377, str. 1-11, DOI: 10.1016/j.mtnano.2023.100377.

3.) REBERC, Maja, MAZAJ, Matjaž, STARE, Jernej, POČKAJ, Marta, MALI, Gregor, LI, Xiao, FILINCHUK, Yaroslav, ČERNÝ, Radovan, MEDEN, Anton. Trinuclear magnesium imidazolate borohydride complex. Inorganic chemistry. [Print ed.]. 2 Aug. 2022, vol. 61, iss. 32, str. 12708-12718, ilustr. ISSN 0020-1669, DOI: 10.1021/acs.inorgchem.2c01319.

MORFOLOŠKA IN TERMIČNA ANALIZA MATERIALOV ZA ENERGETIKO

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Morfološka in termična analiza materialov za energetiko
Course title:	Morphological and Thermal Analysis of Energy Materials
Članica nosilka/UL Member:	UL FKKT

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Kemija, druga stopnja, magistrski (od študijskega leta 2025/2026 dalje)	Materiali za shranjevanje in pretvorbo energije (smer)	2. letnik	1. semester	obvezni

Univerzitetna koda predmeta/University course code:	0190395
Koda učne enote na članici/UL Member course code:	TU17UN

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
20	10	15 LV			45	3

Nosilec predmeta/Lecturer:	izr. prof. dr. Boštjan Genorio, prof. dr. Marjan Marinšek
Vrsta predmeta/Course type:	obvezni/Mandatory
Jeziki/Languages:	Predavanja/Lectures: Angleščina Vaje/Tutorial: Angleščina

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	Prerequisites:
Vpis v 2. letnik MŠP Materiali za shranjevanje in pretvorbo energije. Predmet lahko izberejo tudi tuji študenti na mednarodni izmenjavi na UL, ki morajo imeti podpisan učni sporazum (LA) med UL FKKT in drugimi tujimi izobraževalnimi ustanovami.	Enrolment in the 2nd year of USP "Materials for Energy Storage and Conversion" (MESC). The subject can be attended by international exchange students that have a signed learning agreement between UL FKKT and other foreign educational institution.

Vsebina:	Content (Syllabus outline):
1. Metode določevanja velikosti in porazdelitve velikosti delcev: definicija disperznega sistema, problem določevanja velikosti nepravilnih delcev, meritve velikost delca in porazdelitve velikosti delcev, določevanje faktorjev oblike, definicija specifične površine in meritev specifične površine disperznega sistema, definicija poroznosti in merjenje poroznosti disperznega Sistema. 2. Termoanalitske tehnike: definicija koncepta termične analize, termogravimetrija (TG),	1. Methods for particle size measurement: Definition of disperse systems, particle size determination for irregular particles, particle size and size distribution measurements, shape factor determination, specific surface of a disperse system and specific surface measurements, porosity of a disperse system and porosity measurements. 2. Thermoanalytical techniques: Definition of the concept "thermal analysis". Thermogravimetry

diferenčna termična analiza (DTA) in dinamična kalorimetrija (DSC), TG in DSC kot komplementarni metodi (termična dekompozicija/fazni prehodi). Analiza eksperimentalnih podatkov zajetih s TG, DTA in DSC metodami vzorca neznane sestave. 3. Elektronska, IR in Ramanska spektroskopija: Teoretične osnove IR in Ramanske spektroskopije, principi in primeri IR in Ramanskih meritev. 4. Mikroskopija (optična, elektronska, ionska): Optična in elektronska (SEM, TEM, FIB) mikroskopija, EDS in WDS spektroskopija, elektronska difrakcija v TEM mikroskopiji, mikroskopija na atomsko silo (AFM), vrstična tunelska mikroskopija (STM), primeri mikrostrukturne kvantitativne analize različnih materialov. 5. Površinske tehnike: Rentgenska fotoelektronska spektroskopija (XPS) in Sekundarna ionska masna spektrometrija s časom letenja (ToF-SIMS)	(TG); differential thermal analysis (DTA) and dynamic scanning calorimetry (DSC). TG and DSC as complementary methods (thermal decomposition/phase transition). Analysis of experimental data from TG, DTA and DSC curves, obtained from the compounds with known composition. 3. Electron, IR and Raman spectroscopy: Theory of IR and Raman spectroscopies, Principles and examples of IR and Raman measurements. 4. Microscopy (optical, electron, ion, scanning probe): Optical and electron microscopy (SEM, TEM, FIB), EDS and WDS spectroscopy, electron diffraction in TEM microscopy, atomic force microscopy (AFM), scanning tunneling microscopy (STM), examples of microstructure quantitative analysis of materials. 5. Surface Techniques: X-ray Photoelectron Spectroscopy (XPS) and Time-of-Flight Secondary Ion Mass Spectrometry (ToF-SIMS)

Temeljna literatura in viri/Readings:

1.) D. A. Skoog, F. J. Holler, S. R. Crouch, Principles of instrumental analysis, 7th Edition, Cengage Learning, 2017, 992 strani (50%).
2.) P. Haines, Principles of Thermal Analysis and Calorimetry, Royal Society of Chemistry, 2002, 268 strani (20%).
3.) Paul van der Heide, X-ray Photoelectron Spectroscopy: An introduction to Principles and Practices, John Wiley & Sons, Inc., 2011, 264 strani (20%)
4.) J.R. Ferraro, K. Nakamoto, C.W. Brown, Introductory Raman Spectroscopy, Academic Press, 2003, 434 strani (10%)

Cilji in kompetence:	**Objectives and competences:**
Ob zaključenem kurzu študenti: • Razumejo principe različnih analitskih tehnik s področja ved o materialih • Znajo uporabiti različne analitske tehnike za analitiko energetskih materialov s področja shranjevanja in konverzije energije • Razumejo omejitve pri uporabi različnih analitskih tehnik • Znajo samostojno delati z izbrano sofisticirano analitsko opremo.	At the end of this course students should be able to: • Understand the principles of the various techniques applied in Material science. • Apply individual analysis techniques for novel energy materials related to energy storage and conversion applications. • Understand the limitations of individual techniques. • Be able to perform specific measurements on specific apparatus.

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanje in razumevanje Študentje spoznajo različne analitske tehnike, ki omogočajo poglobljeno analizo različnih energetskih materialov. Uporaba Pridobljeno znanje se lahko uporabi za reševanje problemov povezanih z razvojem naslednje generacije energetskih materialov za shranjevanje in konverzijo energije na akademskem in industrijskem nivoju.	Knowledge and Comprehension Students learn about various techniques that enable thorough characterization of energy materials. Application Acquired knowledge will be used in problem solving for the next generation energy storage and conversion devices in academia and European industry. Analysis

Refleksija Pridobljeno znanje je orodje, ki študentu omogoča reševanje problemov povezanih z alternativnimi tehnologijami prihodnosti. Prenosljive spretnosti Pridobljeno znanje je direktno prenosljivo tudi na druga področja znanosti.	The acquired knowledge is a tool that gives a student the leverage to solving current problems of important alternative technologies of the future. Skill-transference Ability Acquired knowledge is directly transferable to other fields of science.

Metode poučevanja in učenja:	**Learning and teaching methods:**
Predavanja, seminarji, laboratorijsko delo	Lectures, seminars and labwork.

Načini ocenjevanja:	**Delež/Weight**	**Assessment:**
Laboratorijsko delo	30,00 %	Labwork
Pisni izpit	70,00 %	Written exam

Ocenjevalna lestvica:	**Grading system:**
5 - 10, pri čemer velja, da je pozitivna ocena od 6 - 10	5 - 10, a student passes the exam if he is graded from 6 to 10

Reference nosilca/Lecturer's references:

1. ŠTUKOVNIK, Petra, BOKAN-BOSILJKOV, Violeta, **MARINŠEK, Marjan**. ACR progress in concretes with dolomite aggregate and blast furnace slag CEM III binder. Ceramics. 2024, vol. 68, iss. 1, str. 67-79, ilustr. ISSN 0862-5468. https://www.ceramics-silikaty.cz/index.php?page=cs_detail_doi&id=1885, DOI: 10.13168/cs.2024.0006
2. DOLAR, Andraž, DROBNE, Damjana, DOLENEC, Matej, **MARINŠEK, Marjan**, JEMEC KOKALJ, Anita. Time-dependent immune response in Porcellio scaber following exposure to microplastics and natural particles. Science of the total environment. 20 Apr. 2022, vol. 818, str. 1-10, ilustr. ISSN 0048-9697. https://www.sciencedirect.com/science/article/abs/pii/S0048969721068923?via%3Dihub, https://repozitorij.uni-lj.si/IzpisGradiva.php?id=144298, DOI: 10.1016/j.scitotenv.2021.151816.
3. PORI, Maja, ARČON, Iztok, DASIREDDY, Venkata D. B. C., LIKOZAR, Blaž, CRNJAK OREL, Zorica, **MARINŠEK, Marjan.** Photo-chemically-deposited and industrial Cu/ZnO/Al2O3//23 catalyst material surface structures during CO22 hydrogenation to methanol : EXAFS, XANES and XPS analyses of phases after oxidation, reduction, and reaction. *Catalysis letters*. 2021, vol. 151, iss. 11, str. 3114-3134, ilustr. ISSN 1011-372X. https://repozitorij.ung.si/IzpisGradiva.php?id=6568, DOI: 10.1007/s10562-021-03556-1.
4. ROZMAN, Ula, TURK, Tilen, SKALAR, Tina, ZUPANČIČ, Marija, ČELAN KOROŠIN, Nataša, **MARINŠEK, Marjan**, OLIVERO-VERBEL, Jesus, KALČÍKOVÁ, Gabriela. An extensive characterization of various environmentally relevant microplastics - material properties, leaching and ecotoxicity testing. Science of the total environment. 15 Jun. 2021, vol. 773, str. 1-10, ilustr. ISSN 0048-9697. https://www.sciencedirect.com/science/article/pii/S0048969721006446, https://repozitorij.uni-lj.si/IzpisGradiva.php?id=138400, DOI: 10.1016/j.scitotenv.2021.145576.

SODOBNE TEHNIKE SINTEZE MATERIALOV ZA ENERGETIKO

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Sodobne tehnike sinteze materialov za energetiko
Course title:	Modern Techniques for the Synthesis of Energy Materials
Članica nosilka/UL Member:	UL FKKT

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Kemija, druga stopnja, magistrski (od študijskega leta 2025/2026 dalje)	Materiali za shranjevanje in pretvorbo energije (smer)	2. letnik	1. semester	obvezni

Univerzitetna koda predmeta/University course code:	0190396
Koda učne enote na članici/UL Member course code:	TU18UN

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
30		15 LV			45	3

Nosilec predmeta/Lecturer:	prof. dr. Robert Dominko
Vrsta predmeta/Course type:	obvezni/Mandatory
Jeziki/Languages:	Predavanja/Lectures: Angleščina; Vaje/Tutorial: Angleščina

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	Prerequisites:
Vpis v 2. letnik MŠP Materiali za shranjevanje in pretvorbo energije. Predmet lahko izberejo tudi tuji študenti na mednarodni izmenjavi na UL, ki morajo imeti podpisan učni sporazum (LA) med UL FKKT in drugimi tujimi izobraževalnimi ustanovami.	Enrolment in the 2nd year of USP "Materials for Energy Storage and Conversion" (MESC). The subject can be attended by international exchange students that have a signed learning agreement between UL FKKT and another foreign educational institution.

Vsebina:	Content (Syllabus outline):
• Sinteza nanomaterialov: ravnotežje trdne snovi / raztopine v precipitacijskih tehnikah; Sol gel tehnika; Hibridni materiali; Hidrotermalna in templatna sinteza; lastnosti materialov na nanoskali • Uporaba nanomaterialov pri shranjevanju in pretvorbi energije • Karakterizacijske tehnike za nanomateriale • Praktična uporaba nanomaterialov v različnih elektrokemijskih celicah • Prednosti in slabosti uporabe nanomaterialov • Kritična ocena praktične uporabe nanomaterialov	• Nanomaterials Synthesis: Solid/solution equilibria applied to the precipitation; Sol gel technique; Hybrid Materials; Hydrothermal and templating synthesis; Materials at the nanoscale • Application of nanomaterials in energy storage and conversion • Characterization techniques for nanomaterials • Practical implementation of nanomaterials into different electrochemical cells • Advantages and drawbacks of using nanomaterials

	• Critical assessment of nanomaterials in practical application

Temeljna literatura in viri/Readings:

1.) Cao Guozhong, Ying Wang, Nanostructures and Nanomaterials: Synthesis, Properties, and Applications, World scientific publishing Co., 2011, Print ISBN: 9814322504 (60%)
2.) Mahmood Aliofkhazraei, Handbook of Functional Nanomaterials: Application and Development, Nova Science Publishers, 2014, Hardcover ISBN: 1629485667 (20%)
3.) Najnovejša literatura (20%)

Cilji in kompetence:	**Objectives and competences:**
Študenti se seznanijo z različnimi sinteznimi tehnikami za pripravo nanomaterialov za shranjevanje in pretvorbo energije. Med predavanji in seminarji so navedeni različni primeri uporabe nanomaterialov pri shranjevanju in pretvorbi energije. Dodaten poudarek je na karakterizacijskih tehnikah ter prednosti in slabosti nanomaterialov pri shranjevanju in pretvorbi energije. Pri laboratorijskih vajah spoznajo osnove sintez v laboratoriju. Seminarke naloge služijo kot pregled literature za načrtovanje novih korakov pri raziskovalnem delu.	Students are introduced to various synthesis techniques for the preparation of nanomaterials for energy storage and conversion. Different cases of application of nanomaterials in energy storage and conversion are given during the lectures and seminars. Additional emphasizes is on the characterization techniques and advantages and disadvantages of nanomaterials in energy storage and conversion. Students are introduced to basic steps in the synthesis work during labwork. Literature review serves as a critical overview of recent achievements in different fields with aim to plan future research activities.

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanje in razumevanje: Študenti spoznajo različne sintezne pristope za pripravo nanomaterialov, njihove lastnosti, karakterizacijo in uporabo v zvezi z materiali za shranjevanje in pretvorbo energije. Uporaba: Pridobljeno znanje bo uporabljeno v akademskih krogih in evropski industriji pri načrtovanju in sintezi nove generacije aktivnih materialov za naprave za shranjevanje in pretvorbo energije. Refleksija: Pridobljeno znanje je orodje, ki študentu daje vzvod za reševanje trenutnih problemov pomembnih alternativnih tehnologij prihodnosti. Prenosljive spretnosti: Pridobljeno znanje je neposredno prenosljivo na druga znanstvena področja, kot so kemija, kemijsko inženirstvo in elektrotehnika.	Knowledge and Comprehension Students learn about different synthesis approaches for nanomaterials preparation, their properties, characterization and applications related to energy storage and conversion materials. Application Acquired knowledge will be used in the design and synthesis of novel active materials for the next generation energy storage and conversion devices in academia and European industry. Analysis The acquired knowledge is a tool that gives a student the leverage to solving current problems of important alternative technologies of the future. Skill-transference Ability Acquired knowledge is directly transferable to other fields of science such as chemistry, chemical engineering, and electrical engineering.

Metode poučevanja in učenja:	**Learning and teaching methods:**
Predavanja, laboratorijske vaje in seminarske naloge	Lectures, labwork and literature reports

Načini ocenjevanja:	**Delež/Weight**	**Assessment:**
Izpit (pisni)	75,00 %	Exam (Written)
Seminarska naloga	25,00 %	Literature report
Laboratorijske vaje		Labwork

Ocenjevalna lestvica: **Grading system:**

5 - 10, pri čemer velja, da je pozitivna ocena od 6 - 10	5 - 10, a student passes the exam if he is graded from 6 to 10

Reference nosilca/Lecturer's references:

(1) J.-M. Ateba MBA, I. Arčon, G. Mali, E. Tchernychova, R. Witte, R. Kruk, M. Gaberšček, R. Dominko. Ceramic synthesis of disordered lithium rich oxyfluoride materials. J. Power Sources. 467, 228230-1-228230-11 (2020).
(2) R. Narayan, A. Blagojević, G. Mali, J.F. Velez, J. Bitenc, A. Randon-Vitanova, R. Dominko. Nanostructured poly(hydroquinonyl-benzoquinonyl sulfide)/multiwalled carbon nanotube composite cathodes: improved synthesis and performance for rechargeable Li and Mg organic batteries. Chemistry of materials. 34, 6378−6388, (2022)
(3) G. Križan, J. Križan, R. Dominko, M. Gaberscek, Pulse combustion reactor as a fast and scalable synthetic method for preparation of Li-ion cathode materials, J. Power Sources, 363, 218-226 (2017)
(4) F.A, Strauss, G. Rousse, D. Batuk, M. Tang, E. Salager, G. Drazic, R. Dominko, J.-M. Tarascon, Electrochemical behavior of Bi4B2O9 towards lithium-reversible conversion reactions without nanosizing. PCCP. Physical chemistry chemical physics, 20, 2330-2338 (2018).
(5) Dominko, R; Bele, M; Gaberscek, M; Meden, A; Remskar, M; Jamnik, J, Structure and electrochemical performance of Li2MnSiO4 and Li2FeSiO4 as potential Li-battery cathode materials, Electrochem Commun. 8, 217-220 (2007)
(6) Bobnar, J.; Lozinšek, M.; Kapun, G.; Njel, C.; Dedryvère, R.; Genorio, B.; Dominko, R. Fluorinated Reduced Graphene Oxide as a Protective Layer on the Metallic Lithium for Application in the High Energy Batteries. *Sci. Rep. 8*, 5819 (2018).

NAPRAVE ZA SHRANJEVANJE IN PRETVORBO ENERGIJE II

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Naprave za shranjevanje in pretvorbo energije II
Course title:	Energy Storage and Conversion Devices II
Članica nosilka/UL Member:	UL FKKT

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Kemija, druga stopnja, magistrski (od študijskega leta 2025/2026 dalje)	Materiali za shranjevanje in pretvorbo energije (smer)	2. letnik	1. semester	obvezni

Univerzitetna koda predmeta/University course code:	0190397
Koda učne enote na članici/UL Member course code:	TU19UN

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
30	15	15 LV			60	4

Nosilec predmeta/Lecturer:	prof. dr. Miran Gaberšček
Vrsta predmeta/Course type:	obvezni/Mandatory
Jeziki/Languages:	Predavanja/Lectures: Angleščina Vaje/Tutorial: Angleščina

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	Prerequisites:
Vpis v 2. letnik MŠP Materiali za shranjevanje in pretvorbo energije. Predmet lahko izberejo tudi tuji študenti na mednarodni izmenjavi na UL, ki morajo imeti podpisan učni sporazum (LA) med UL FKKT in drugimi tujimi izobraževalnimi ustanovami.	Enrolment in the 2nd year of USP "Materials for Energy Storage and Conversion" (MESC). The subject can be attended by international exchange students that have a signed learning agreement between UL FKKT and another foreign educational institution.

Vsebina:	Content (Syllabus outline):
Energijski koncepti Primarne in sekundarne baterije (akumulatorji), konvencionalni fosilni viri energije, ne-fosilni primarni viri in nosilci energije, neobnovljivi in obnovljivi viri energije, pretvorba energije (termodinamski vidiki in učinkovitost), trenutna poraba energije in s tem povezani problemi, prihajajoče nove tehnologije in različni scenariji za prihodnost **Naprave za shranjevanje energije** Uvod in primerjava najpomembnejših sodobnih naprav za shranjevanje energije, kot so baterije,	**Energy concepts** Primary vs. secondary energy sources (energy carriers), conventional fossil fuel sources, non-fossil primary sources and energy carriers, non-renewable vs. renewable energy sources, conversion of energy (thermodynamics and efficiency aspects), state-of-the art energy consumption and issues, possible future technologies and scenarios **Energy Storage Devices** Introduction and comparison of main modern storage devices such as batteries, capacitors, supercapacitors, flywheels, magnetic ESDs, pumped

kondenzatorji, superkondenzatorji (elektrokemijski kondenzatorji), vztrajniki, magnetni načini shranjevanja energije, črpalne hidroelektrarne, shranjevanje vodika. Obravnava kriterijev za selekcijo najprimernejših tehnologij: tehnična zrelost, upravljanje/uravnavanje obremenitev, vpliv na okolje (biološka obremenitev, učinek tople grede ipd.), kvaliteta (specifične) moči naprave, učinkovitost, stroški. **Baterijske tehnologije** Zgodovinski razvoj v z vidika razvoja mehanizmov in kemizma shranjevanja energije v baterijskih napravah. Podrobna predstavitev najpomembnejših sistemov (svinčeve baterije, nikelj-kadmij, nikelj-kovinski hidrid, litij-ionske baterije, natrijeve baterije, baterije litij-žveplo, baterije s kovinskim litijem, redoks pretočne baterije, baterije iz trdnih faz). Prednosti in slabosti različnih sistemov. Predstavitev in podrobnejša obravnava tipičnih odprtih vprašanj, povezanih s sodobnimi baterijskimi sistemi, predstavitev usmeritev za prihodnost. Okoljski vidiki baterijskih tehnologij in reciklaža materialov. **Proizvodnje vodika, njegov transport, shranjevanje in uporaba v gorivnih celicah** Uvodna predstavitev vodika kot enega najpomembnejših nosilcev energije v ekonomiji prihodnosti. Obravanava aktualnih in prihajajočih tehnologij za proizvodnjo vodika: elektroliza, fotoliza, termoliza, proizvodnja iz biomase, termikemični cikli. Podroben prikaz delovanja glavnih vrst gorivnih celic in elektrolizatorjev: alkalnih, s protonsko izmenjevalno membrano, na osnovi trdnih oksidov, fosforjevih, z elektrolitom iz staljenih karbonatov itd. Uvod v fotoelektrokemijske celice in naprave. Primerjava tehnologij z vidika zrelosti, učinkovitosti, predstavitev odprtih vprašanj. Obravnava klasičnih tehnologij za shranjevanje vodika: shranjevanje plinastega vodika, utekočinjanje vodika in njegovo shranjevanje. Transportne tehnolgije, varnostni vidiki. Okoljski vidiki vodikovih tehnologij in reciklaža materialov. **Shranjevanje vodika v kovinskih hidridih in kompleksnih hidridih** Uvod v splošne principe in metode kemijskega shranjevanja vodika. Termodinamski vidiki shranjevanja vodika v kovinskih hidridih. Predstavitev najobetavnejših preprostih hidridov za uporabo v vodikovi ekonomiji (magnezijevi hidridi oz. hidridi prehodnih kovin). Kompleksni kovinski hidridi (na primer NaAlH4, LiAlH4, LiBH4 ipd.). Vpliv nanostrukturiranosti na različne vidike shranjevanja (kapaciteta, kinetika, ciklabilnost, temperatura sproščanja, cena itd.).	hydro energy storage , hydrogen storage. Various selection criteria will be discussed: load management, technical maturity, environmental impact (biological impact, greenhouse gas emissions etc.), power quality, efficiency, costs. **Battery technologies** Historical development in the context of storage mechanisms and chemistries. Detailed presentation of the most important systems (lead-acid, nickel-cadmium, nickel-metal hydride, lithium ion, sodium ion, lithium metal, metal air, redox flow, all solid state batteries etc.). Advantages and disadvantages of various systems. Presentation of open questions in modern systems, discussion of possible solution and research directions. Environmental costs of battery techologies and recycling of materials. **Hydrogen production, transport and storage and its usage in fuel cells** Introduction of hydrogen as important future energy carrier. Presentation of emerging hydrogen production technologies: electrolysis, photolysis, thermolysis, production from biomass, thermochemical cycles. Detailed discussion of the performance of main types of fuel cells and electrolyzers: alkaline, proton exchange membrane, solid oxide, phosphoric, molten carbonate etc. Introduction in photoelectrochemical cells and devices. Comparison in terms of maturity, efficiency, discussion of open issues. Classical hydrogen storage technologies: gaseous hydrogen storage, hydrogen liquefaction, liquid hydrogen storage. Transport technologies including safety issues. Environmental costs of hydrogen techologies and recycling of materials. **Hydrogen storage in metal hydrides and complex hydrides** Introduction to general chemical hydrogen storage principles and methods. Thermodynamic aspects of hydrogen storage in metal hydrides. Presentation of most promising simple hydrides for use in a hydrogen economy (magnesium or transition metals hydrides), complex metal hydrides (for example NaAlH4, LiAlH4, LiBH4 etc.). The impact of nanostructurization on performance requirements for storage (capacity, kinetics, cyclability, cost, release temperature).

Temeljna literatura in viri/Readings:

1.) R.A. Huggins, Energy Storage: Fundamentals, Materials and Applications, Springer; 2nd ed. 2016 edition (November 14, 2015).
2.) Vitalie Stavila, Lennie Klebanoff, Metal Hydrides, D. Stolten, R. C. Samsun, N, Garland, Eds., 2016 Wiley-VCH Verlag GmbH & Co. KgaA, Wiley online library, https://doi.org/10.1002/9783527693924.ch16
3.) William M. Mueller (Editor), James P. Blackledge (Editor), George G. Libowitz (Editor), Metal Hydrides, Academic Press (September 12, 2013).

Cilji in kompetence:	**Objectives and competences:**
Cilji: Poglobljen študij: - konceptov izdelave in mehanizmov delovanja najpomembnejših relevantnih sistemov za shranjevanje energije - veličin, parametrov, s katerimi evalviramo delovanje različnih sistemov za shranjevanje - potreb, problemov ki jih rešujemo z razvojem obravnavanih sistemov - principa delovanja različnih baterijskih naprav, njihovih komponent in njijovih lastnosti - principa delovanja različnih kovinskih hidridov ter njijovih lastnosti **Kompetence:** Splošne kompetence: razumevanje osnovnih principov delovanja najpomembnejših obstoječih sistemov za shranjevanje energije. Sposobnost kvalitativne in kvantitativne primerjave različnih sistemov za shranjevanje energije. Pridobljena splošna znanja so nato usmerjena v razumevanje in uposabljanje za raziskovalno delo na področju baterij in kovinskih hidridov	**Objectives:** In depth study of: - Concepts and operation of available and relevant energy storage systems - Comparison tools used in system evaluation. - Different needs within energy storage - Principle of operation of different battery devices, their main components and properties - Principle of operation of different metal hydrides and their main properties **Competences:** General competence: The candidate is expected to manage basic principles for accessible and relevant energy storage systems and quantitatively and qualitatively be able to compare these. Special emphasis is on understanding the operation and properties of batteries and metal hydrides. Acquired knowledge is the basis for training and applied work either in research or in routine laboratory work in the field of electrochemistry.

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanje in razumevanje Študent pridobi temeljna znanja, potrebna za razumevanje delovanja naprav za shranjevanje energije. Podrobno razume delovanje sodobnih baterijskih naprav in mehanizme shranjevanja energije v obliki kovinskih hidridov. Sposoben je sestaviti enostavno baterijsko celico in izmeriti njene glavne karakteristike. Uporaba Pridobljeno splošno in teoretično znanje je usmerjeno v poznavanje delovanja konkretnih aplikacij s področja shranjevanja energije, predvsem baterij in kovinskih hidridov. Deloma je zajeta tudi obravnava nekaterih drugih sodobnih naprav za shranjevanje energije. Študent se na teh področjih usposobi za samostojno raziskovalno delo in spozna načine prenosa in uporabe teoretskih zakonitosti v praksi. Refleksija Pridobljeno teoretično znanje omogoča študentu poglobljen vpogled v osnovne koncepte in zakonitosti na področju shranjevanja energije. Dodatno študent pridobi veščine prenosa osnovnih znanj na izbrane praktične primere, kot so baterije, kovinski hidridi in podobno. Vsebina in izvedba	Knowledge and Comprehension The student acquires base knowledge needed for understanding operation of devices for energy storage. He understands in detail the operation of modern battery systems and mechanisms of energy storage in metal hydrides. He is able to construct a simple battery cell and measure its main characteristics. Application Acquired base knowledge is implemented in selected energy storage applications, in particular in batteries and metal hydrides. Partly the mechanisms of other modern storage systems are also highlighted and discussed. electroanalytical methods etc. Student becomes qualified for independent research in the field and gets knowledge about transfer of theoretical concepts into practice. Analysis Acquired theoretical knowledge enables a profound insight into main concepts and laws in the field of energy storage devices. Additionally, the student acquires the ability to apply knowledge base into selected practical examples. The curriculum represents a solid background for later active and

predmeta predstavlja dobro osnovo za kasnejše aktivno in samostojno udejstvovanje na področju raziskav in uporabe znanj s področja shranjevanja energije v praksi. Prenosljive spretnosti Pridobi veščine na področju konceptov in naprav za shranjevanje energije, zna uporabljati znanstveno in strokovno literaturo ter pravilno predstaviti in razlagati merske rezultate. Pridobi znanja, potrebna za projektno in timsko delo.	independent research in the fields of basic and applied research in the field of storage devices, in particular batteries and metal hydrides. Skill-transference Ability Student acquires experimental skills in the field of energy storage devices, masters the use of scientific and professional literature and develops the skill of presenting and explaining complex and specific results to wider audience. Competences needed for project and team work are also developed.

Metode poučevanja in učenja:	**Learning and teaching methods:**
Predavanja, seminarji, laboratorijsko delo	Lectures, tutorial, labwork

Načini ocenjevanja:	**Delež/Weight**	**Assessment:**
Pisni izpit	100,00 %	Written exam

Ocenjevalna lestvica:	**Grading system:**
5 - 10, pri čemer velja, da je pozitivna ocena od 6 - 10	5 - 10, a student passes the exam if he is graded from 6 to 10

Reference nosilca/Lecturer's references:

1. GABERŠČEK, Miran. Understanding Li-based battery materials via electrochemical impedance spectroscopy. Nature communications. 11 Nov. 2021, vol. 12, str. 1-4, ilustr. ISSN 2041-1723. https://www.nature.com/articles/s41467-021-26894-5, DOI: 10.1038/s41467-021-26894-5
2. LI, Yiyang, CHEN, Hungru, LIM, Kipil, DENG, Haitao D., LIM, Jongwoo, FRAGGEDAKIS, Dimitrios, ATTIA, Peter M., LEE, Sang Chul, JIN, Norman, MOŠKON, Jože, GUAN, Zixuan, GENT, William E., HONG, Jihyun, YU, Young-Sang, GABERŠČEK, Miran, ISLAM, M. Saiful, BAZANT, Martin Z., CHUEH, William C. Fluid-enhanced surface diffusion controls intraparticle phase transformations. *Nature materials*, 2018, vol. 17, iss. 10, str. 915-922.
3. PAVKO, Luka, GATALO, Matija,…, GABERŠČEK, Miran. Graphene-derived carbon support boosts proton exchange membrane fuel cell catalyst stability. ACS catalysis. 2022, vol. 12, iss. 15, str. 9540–9548, FRANCO, Alejandro A., RUCCI, Alexis, BRANDELL, Daniel, FRAYRET, Christine, GABERŠČEK, Miran, JANKOWSKI, Piotr, JOHANSSON, Patrik. Boosting rechargeable batteries R&D by multiscale modeling : myth or reality?. *Chemical reviews*, 2019, vol. 119, iss. 7, str. 4569-4627.
4. MENGA, Davide, LOW, Jian Liang, LI, Yan-Sheng, ARČON, Iztok, KOYUTÜRK, Burak, WAGNER, Friedrich, RUIZ-ZEPEDA, Francisco, GABERŠČEK, Miran, PAULUS, Beate, FELLINGER, Tim-Patrick. Resolving the dilemma of Fe-N-C catalysts by the selective synthesis of tetrapyrrolic active sites via an imprinting strategy. Journal of the American Chemical Society. [Online ed.]. 2021, vol. 143, iss. 43, str. 18010-18019, https://pubs.acs.org/doi/pdf/10.1021/jacs.1c04884

ISKANJE LITERATURE, PRIPRAVA PROJEKTNIH PREDLOGOV IN INTELEKTUALNA LASTNINA TER MEHKE VEŠČINE IN STROKOVNI RAZVOJ

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Iskanje literature, priprava projektnih predlogov in intelektualna lastnina ter mehke veščine in strokovni razvoj
Course title:	Tools for Bibliography Search, Fund hunting, Intellectual Property - Soft Skills and Professional Development
Članica nosilka/UL Member:	UL FKKT

Študijski programi in stopnja	**Študijska smer**	**Letnik**	**Semestri**	**Izbirnost**
Kemija, druga stopnja, magistrski (od študijskega leta 2025/2026 dalje)	Materiali za shranjevanje in pretvorbo energije (smer)	2. letnik	1. semester	obvezni

Univerzitetna koda predmeta/University course code:	0190398
Koda učne enote na članici/UL Member course code:	TU20-1UN

Predavanja /Lectures	**Seminar /Seminar**	**Vaje /Tutorials**	**Klinične vaje /Clinical tutorials**	**Druge oblike študija /Other forms of study**	**Samostojno delo /Individual student work**	**ECTS**
30	30				60	4

Nosilec predmeta/Lecturer:	prof. dr. Robert Dominko
Vrsta predmeta/Course type:	obvezni/Mandatory

Jeziki/Languages:	Predavanja/Lectures:	Angleščina
	Vaje/Tutorial:	

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	**Prerequisites:**
Vpis v 2. letnik MŠP Materiali za shranjevanje in pretvorbo energije. Predmet lahko izberejo tudi tuji študenti na mednarodni izmenjavi na UL, ki morajo imeti podpisan učni sporazum (LA) med UL FKKT in drugimi tujimi izobraževalnimi ustanovami.	Enrolment in the 2nd year of USP "Materials for Energy Storage and Conversion" (MESC). The subject can be attended by international exchange students that have a signed learning agreement between UL FKKT and an other foreign educational institution.

Vsebina:	**Content (Syllabus outline):**
• Različne vrste iskalnikov za bibliografijo • Klasifikacija raziskovalne literature • Zaščita znanja, definicija intelektualne lastnine • Pisanje patentne prijave • Razlika med patentnimi prijavami • Od znanstvene ideje do obsežnega projekta • Vodenje projektov in poročanje	• Different types of bibliography search engines • Classification of research literature • Knowhow protection, intellectual property definition • Patent application writing • Difference between patent applications • From scientific idea to large scale project

• industrijski projekti • predstavitev rezultatov • poročanje o rezultatih • predstavitvena retorika • profesionalni razvoj	• Project coordination and reporting • Industrial projects • Results presentation • Results reporting • Presentation rhetoric • Professional development

Temeljna literatura in viri/Readings:

1.) https://ec.europa.eu/research/participants/docs/h2020-funding-guide/grants/applying-for-funding/submit-proposals_en.htm
2.) L. Bently and B. Sherman, Intellectual Property Law, Oxford University Press; 3rd edition (November 15, 2008), ISBN-13: 978-0199292042
3.) Getting Skills Right: Skills for Jobs Indicators, OECD, DOI:https://dx.doi.org/10.1787/9789264277878-en ISBN: 978-92-64-27786-1 (print version)
4.) Key competences for lifelong learning; EU Commission document; 2019 ISBN: 978-92-76-00475-2
5.) Najnovejša literatura (ključne beside: uspešen projekt, kako pripraviti patentno vlogo, kako napisati znanstveno poročilo, …

Cilji in kompetence:	**Objectives and competences:**
Ob koncu tega predmeta bi morali imeti študenti dovolj informacij za: • iskanje literature z različnimi iskalniki; • pisanje projektnih predlogov; • ustrezna zaščita intelektualne lastnine; • priprava patentne prijave; • predlog projekta za industrijskega partnerja; • strukturiranje rezultatov v izčrpno poročilo / predlog članka / magistersko delo; • poročajo o rezultatih pred različnimi skupnostmi (strokovna, nestrokovna ali laična javnost); • priprava poročil in predstavitve, ki je razumljiva, brez balasta, gladka in logična; • študent bo dobil vpogled v strokovni razvoj s poudarkom na možnostih doktorskega študija in potencialnem podoktorskem študiju.	At the end of this course students should have enough information for: • Searching for the literature by using different search engines; • Writing a proposal for governmental founds; • Proper protection of intellectual property; • Drafting patent application; • Convincing industrial partner to invest in her/his research; • structure results into the comprehensive report/manuscript/thesis; • report results in front of different communities (professional, public or laic community); • preparation of the reports and presentation which is understandable, without ballast, smooth and logical; Student will get insights about professional development, with a focus on possibilities in the PhD study and potential postdoctoral research studies.

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanje in razumevanje: Študenti se bodo naučili, kako iskati literaturo, katere iskalnike je mogoče uporabiti, kako razvrstiti raziskovalno literaturo in kako prepoznati zanesljive rezultate. Študenti se naučijo predstaviti rezultate na razumljiv način, kako pisati poročila, magistrska in doktorska dela, predloge člankov. Študentje dobijo nekaj vpogleda v možnost razvoja po magistrskem študiju v akademskem in zasebnem sektorju. V drugem delu bodo dobili razlago o različnih možnostih za zaščito intelektualne lastnine, kako izpolniti patentne prijave, kaj je pomembno in kakšne so razlike med različnimi možnostmi. Tretji del predmeta bo namenjen pisanju projektov, individualni – različne štipendije in obsežni projekti.	Knowledge and Comprehension Students will learn how to search for the literature, which search engines can be used, how to classify research literature and how to recognize trustable results. Students learn how to present results in the understandable way, how to write reports, thesis, manuscripts, policy of publishers. Students get some insights about possibility of carrier development after master study in academia and private sector. In the second part of the course they will get explanations about different possibilities to protect intellectual property, how to fill in patent applications, what is important and what are differences between different options. Third part of the course will be devoted to writing project, small – individual fellowships and large scale collaboration

Kako delati v velikih konzorcij in kako dobiti neposredne pogodbe z industrijo. Uporaba: Pridobljeno znanje bo uporabljeno pri kariernem in osebnem razvoju. Refleksija: Pridobljeno znanje je orodje, ki študentu pomaga pri njegovem poklicnem in osebnem razvoju. Prenosljive spretnosti: Pridobljeno znanje je zelo koristno pri osebnem razvoju, pravilni zaščiti intelektualne lastnine in uspešnem delu v različnih projektih.	projects. How to work in large consortiums and how to get direct contracts with industry. Application Acquired knowledge will be used in carrier development. Analysis The acquired knowledge is a tool that helps to the student in her/his personal carrier development. Skill-transference Ability Acquired knowledge is widely useful in personal development, proper handing with intellectual property and successful work in different projects.

Metode poučevanja in učenja:	**Learning and teaching methods:**
Predavanja, seminarji	Lectures and seminars.

Načini ocenjevanja:	**Delež/Weight**	**Assessment:**
Izpit (pisni del)	60,00 %	Research proposal (Written part)
Seminar (prezentacija, diskusija)	40,00 %	Research proposal (Presentation, Discussion)

Ocenjevalna lestvica:	**Grading system:**
5 - 10, pri čemer velja, da je pozitivna ocena od 6 - 10	5 - 10, a student passes the exam if he is graded from 6 to 10

Reference nosilca/Lecturer's references:

(1) Član komisije za inovacije na Kemijskem inštitutu, Ljubljana, Slovenija in konzultant industriji na področju materialov in kemije v prostem času.
(2) Bele M.; Dominko R.; Pivko M.; Gaberšček M.; A two-step synthesis method for the preparation of composites of insertion active compounds for lithium-ion batteries : patent : EP2619137 (B1), 2016-07-20. Hague: European Patent Office, 2016. 14 str., ilustr. [COBISS.SI-ID 5966618]
patentna družina: WO 2012/039687 (A1), 2012-03-29; SI23488 (A), 2012-03-30
(3) Pavia D.; Lemaitre M.; Dominko R.; Engelen R.; Jacques P.; Jarva K.; Malkamaki M.; Clean energy industrial forum : reinventing regional and local sustainable value chains : lecture at the EU Industry Days 2019, Brussels, 5-6 February 2019. [COBISS.SI-ID 6572570]
(4) Dominko R. New generation of the high energy density lithium batteries : [lecture at conference] Research policy within the european cohesion policy, 17-18 November, 2011, Brdo pri Kranju, Slovenia. Brdo pri Kranju: Government office for local self-government and regional policy, 2011. [COBISS.SI-ID 4861210]
(5) Dominko R. Future trends in battery material technologies : invited lecture at the EIC Prize: Innovative Batteries, 12 May, 2017, Brussels, Belgie. [COBISS.SI-ID 6151962]
(6) Dominko R. Coordination of EU FP7 project - experience from Eurolis : lecture at Fourth Regional Symposium on Electrochemistry, South-East Europe, May 26-30, 2013, Ljubljana, Slovenia. Ljubljana/

(1) Member of the group responsible for patents at National Institute of Chemistry, Ljubljana, Slovenia and strategy and innovation consultant for the material and chemical industry on spare time.
(2) Bele M.; Dominko R.; Pivko M.; Gaberšček M.; A two-step synthesis method for the preparation of composites of insertion active compounds for lithium-ion batteries : patent : EP2619137 (B1), 2016-07-20. Hague: European Patent Office, 2016. 14 str., ilustr. [COBISS.SI-ID 5966618]
patentna družina: WO 2012/039687 (A1), 2012-03-29; SI23488 (A), 2012-03-30
(3) Pavia D.; Lemaitre M.; Dominko R.; Engelen R.; Jacques P.; Jarva K.; Malkamaki M.; Clean energy industrial forum : reinventing regional and local sustainable value chains : lecture at the EU Industry Days 2019, Brussels, 5-6 February 2019. [COBISS.SI-ID 6572570]
(4) Dominko R. New generation of the high energy density lithium batteries : [lecture at conference] Research policy within the european cohesion policy, 17-18 November, 2011, Brdo pri Kranju, Slovenia. Brdo pri Kranju: Government office for local self-government and regional policy, 2011. [COBISS.SI-ID 4861210]

(5) Dominko R. Future trends in battery material technologies : invited lecture at the EIC Prize: Innovative Batteries, 12 May, 2017, Brussels, Belgie. [COBISS.SI-ID 6151962]
(6) Dominko R. Coordination of EU FP7 project - experience from Eurolis : lecture at Fourth Regional Symposium on Electrochemistry, South-East Europe, May 26-30, 2013, Ljubljana, Slovenia. Ljubljana

ANALIZNA (ELEKTRO)KEMIJA IN ELEKTROKATALIZA

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Analizna (elektro)kemija in elektrokataliza
Course title:	Analytical (Electro)Chemistry & Electrocatalysis
Članica nosilka/UL Member:	UL FKKT

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Kemija, druga stopnja, magistrski (od študijskega leta 2025/2026 dalje)	Materiali za shranjevanje in pretvorbo energije (smer)	2. letnik	1. semester	obvezni

Univerzitetna koda predmeta/University course code:	0190400
Koda učne enote na članici/UL Member course code:	TU23UN

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
30	15	30 LV			75	6

Nosilec predmeta/Lecturer:	prof. dr. Mitja Kolar
Vrsta predmeta/Course type:	obvezni/Mandatory
Jeziki/Languages:	Predavanja/Lectures: Angleščina; Vaje/Tutorial: Angleščina

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	Prerequisites:
Vpis v 2. letnik MŠP Materiali za shranjevanje in pretvorbo energije. Predmet lahko izberejo tudi tuji študenti na mednarodni izmenjavi na UL, ki morajo imeti podpisan učni sporazum (LA) med UL FKKT in drugimi tujimi izobraževalnimi ustanovami.	Enrolment in the 2nd year of USP "Materials for Energy Storage and Conversion" (MESC). The subject can be attended by international exchange students that have a signed learning agreement between UL FKKT and another foreign educational institution.

Vsebina:	Content (Syllabus outline):
Uvod v analizno kemijo (opredelitev, pomen, delitev analizne kemije-podpodročja, temeljni analizni pojmi: analit , matrica, merjenec, metoda, tehnika itd.). Stopnje in izbira analiznih postopkov, vrednotenje analiznih rezultatov, validacija metod in postopkov, napake v analizni kemiji. Pomen in vrste kalibracije (metoda umeritvene krivulje, metoda standardnega dodatka, metoda internega standarda). Gravimetrija (princip in uporabnost gravimetrične analize, primeri gravimetričnih določitev). Volumetrija: nevtralizacijske, kompleksiometrične, obarjalne in redoks določitve (potek titracijskih	Introduction to analytical chemistry, terminology, specific analytical statement of a problem, selection of a procedure. Evaluation and presentation of analytical results, sources and types of errors, validation. Calbration in analytical chemistry (method of linear calibration, method of standard additions, method of internal standard). Gravimetric analysis (properties, application and examples of gravimetric procedures). Volumetric analytical methods: neutralisation, redox, precipitation and complex-formation titrations

krivulj, načini ugotavljanja končne točke, izbira indikatorjev, izbrani primeri določitev, avtomatizacija). Uvod v elektrokemijo, pregled elektrokemijskih metod: potenciometrija (značilnosti, merilni sistem, vrste elektrod in uporabnost), voltametrija (značilnosti metode, merilni sistem, voltamogram-interpretacija, sodobni elektrodni materiali, tehnike). Konduktometrija, kulometrija, amperometrija in elektrogravimetrija (značilnosti metod in njihova uporabnost). Ob elektrokemijskih tehnikah bodo predstavljene tudi osnove elektrokatalize na različnih heterogenih materialih, vključno z nanomateriali in reakcijami na površini katalizatorjev, kot sta adsorpcija, desorpcija itd. Za primerjavo katalitskih lastnosti in aktivnost različnih elektrodnih materialov bo uporabljena gostota toka pri konstantni prenapetosti ali prenapetost pri konstantni gostoti toka. Uvod v spektroskopijo in pregled spektroskopskih metod. Molekularna absorpcijska in fluorescenčna spektrometrija (uporaba spektrometrije v UV-VIS in IR področju, lastnosti spektrov, instrumentacija). Atomska emisijska spektromerija (AES) v plamenu in plazmi - ICP. Elektrotermična (ETAAS) in absorpcijska spektromerija (AAS) v plamenu. Separacijske metode: princip kromatografske ločbe in delitev kromatografskih tehnik - tankoplastna kromatografija (TLC), tekočinska kromatografija visoke ločljivosti (HPLC) in plinska kromatografija (GC) (različne izvedbe sistemov, sklopitve, uporabnost). Laboratorijske vaje: pri vajah se slušatelji usposobijo za praktično izvedbo klasičnih in instrumentalnih analiznih metod.	(titration curve, types of indicators, analytical applications, automatization.) Introduction to electrochemistry and electrochemical methods: Potentiometry (method characteristics, measuring system, types of electrodes, approaches for determining concentration, potentiometric titrations) - Voltammetry (method characteristics, measuring system, voltamogram-interpretation, novel electrode materials, techniques). Conductometry, coulometry, amperometry and electrogravimetry (method characteristics and analytical applications). In addition to electro-analytical techniques, electrocatalysis on various heterogeneous materials including nano-materials and reactions on the surface of catalysts such as adsorption, desorption ect. are also presented. The current density at constant overpotential or the overpotential at constant current density is presented in order to compare the catalytic activity of different electrode materials. Introduction to spectroscopy and principles of spectroscopic methods. Molecular absorption and fluorescence spectrometry (method and spectra characteristics, UV-VIS and IR spectrometry, instrumentation). Flame emission (AES) and inductively coupled plasma (ICP) spectrometry. Atomic absorption spectrometry (AAS) and atomic absorption spectrometry with electrothermal atomization (ETAAS). Separation methods: fundamentals of chromatography and principles of different chromatographic methods: thin layer chromatography (TLC), high performance liquid chromatography (HPLC) and gas chromatography (instrumential setup, hyphenation, analytical applications). Laboratory work, performing selected classical and instrumental analytical methods.

Temeljna literatura in viri/Readings:

1.) Harris D. C. Quantitative Chemical Analysis, W. H. Freeman and Company. Eighth Edition, 2010.
2.) Skoog D. A., West D. M., Holler J. F. in Crouch R. S. Fundamentals of analytical chemistry. Ninth Edition, Brooks/Cole. 2014.
3.) Wang J., Analytical Electrochemistry, Wiley-VCH. Second Edition, 2001.

Cilji in kompetence:	**Objectives and competences:**
Pri predmetu slušatelj osvoji temelje analizne kemije, spozna različne analizne pristope in uporabo klasičnih ter instrumentalnih analiznih metod za reševanje realnih primerov.	Student learns the fundamentals of analytical chemistry, analytical approach and application of classical and instrumental analytical methods for real sample analysis.

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanje in razumevanje	Knowledge and Comprehension

Študent razume temelje analizne kemije, osvoji analizni pristop ter razume in zna uporabljati klasične in instrumentalne analizne metode, s poudarkom na pravilni interpretaciji analiznih rezultatov. Uporaba Študent zna podajati in vrednotiti analizne rezultate ter razlikuje med različnimi principi določitev. Študent obvlada računske vidike obravnavanih analiznih metod. Refleksija Študent ima kritičen odnos do rezultatov analiz in predstavljenih analiznih metod. Prenosljive spretnosti Laboratorijske spretnosti, pravilno podajanje in statistično vrednotenje analiznih rezultatov.	Student understands the fundamentals of analytical chemistry, analytical approach and background and applications of classical and selected instrumental analytical methods with proper interpretation of analytical results. Application Student develops ability of presenting and evaluating analytical results. Student masters calculation procedures related to the presented analytical methods. Analysis Student develops critical attitude towards analytical results and presented analytical methods. Skill-transference Ability Laboratory skills, expression of analytical results with statistical evaluation.

Metode poučevanja in učenja:	**Learning and teaching methods:**
Predavanja, vodeni razgovori, sodelovalno učenje, reševanje problemov, laboratorijske vaje.	Lectures, guided discussions, cooperative learning, problem solving.

Načini ocenjevanja:	**Delež/Weight**	**Assessment:**
Laboratorijske vaje	50,00 %	Lab work
Pisni izpit	50,00 %	Written exam

Ocenjevalna lestvica:	**Grading system:**
5 - 10, pri čemer velja, da je pozitivna ocena od 6 - 10	5 - 10, a student passes the exam if he is graded from 6 to 10

Reference nosilca/Lecturer's references:

1.) KOLAR, Mitja, ORAŽEM, Tilen, JOVANOVSKI, Vasko, HOČEVAR, Samo B. Copper film electrode for sensitive detection of nitrophenols. *Sensors and actuators. B, Chemical.* [Print ed.]. 1 Mar. 2021, vol. 330, str. 129338-1-129338-6. ISSN 0925-4005.
2.) GRIČAR, Ema, KALCHER, Kurt, GENORIO, Boštjan, KOLAR, Mitja. Highly sensitive amperometric detection of hydrogen peroxide in saliva based on N-doped graphene nanoribbons and 2 modified carbon paste electrodes. *Sensors*. Dec. 2021, vol. 21, iss. 24, str. 1-14, ilustr. ISSN 1424-8220.
3.) OBREZ, Domen, KOLAR, Mitja, TASIĆ, Nikola, HOČEVAR, Samo B. Study of different types of copper electrodes for anodic stripping voltammetric detection of trace metal ions. *Electrochimica acta*. 20 Jul. 2023, vol. 457, [article no.] 142480, str. 1-11, ilustr. ISSN 1873-3859.

MAGISTRSKO DELO

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Magistrsko delo
Course title:	Master Thesis
Članica nosilka/UL Member:	UL FKKT

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Kemija, druga stopnja, magistrski	Materiali za shranjevanje in pretvorbo energije (smer)	2. letnik	2. semester	obvezni

Univerzitetna koda predmeta/University course code:	0190437
Koda učne enote na članici/UL Member course code:	MAG-MESC

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
				450	450	30

Nosilec predmeta/Lecturer:

Vrsta predmeta/Course type: obvezni/Mandatory

Jeziki/Languages:

Predavanja/Lectures:	Angleščina
Vaje/Tutorial:	Angleščina

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	Prerequisites:
Predmet imajo opredeljen kot študijsko obveznost študenti, ki so vključeni v projekt "Materiali za shranjevanje in pretvorbo energije +" (MESC+). Lahko ga vpišejo tudi drugi tuji študenti na mednarodni izmenjavi na UL. Študenti morajo biti vpisani na MŠP Kemija, 2. stopnja, ali imeti podpisan učni sporazum (LA) med UL FKKT in drugimi tujimi izobraževalnimi ustanovami.	This course will be assigned to the students who are part of the "Materials for Energy Storage and Conversion +" (MESC+) project. It is available to other foreign international exchange students as well. Students must be enrolled to the USP Chemistry, 2nd Cycle or have signed learning agreement between UL FKKT and other foreign educational institution.

Vsebina:	Content (Syllabus outline):
Magistrsko delo se opravlja na področju kemije, smer MESC+. Vsebina in naslov se določata v soglasju z izbranim mentorjem.	Master thesis is performed in one of the areas of chemistry, study field MESC+. Contents and master thesis title are agreed upon with the mentor/supervisor.

Temeljna literatura in viri/Readings:

Knjige in članki, ki so povezani z vsebino magistrskega dela.
Books and journal articles related to the research topic.

Cilji in kompetence:	Objectives and competences:
Cilj: Dokončno oblikovanje pričakovanega lika magistranta. Študent bo ob izdelavi magistrske naloge pokazal sposobnosti iskanja in zaznavanja kemijskih problemov in znal poiskati rešitev za tak problem. *Kompetence:* Pri delu bo pokazal, da je pridobil večino kompetenc navedenih v programu študija.	Final formation of the competences of a master degree candidate. Through carrying out research for the master thesis, students should be able to demonstrate the skills for autonomous identification of a problem and finding solutions, thus proving that specific competences from other courses have been acquired.

Predvideni študijski rezultati:	Intended learning outcomes:
Znanje in razumevanje Pri izdelavi magistrskega dela bo slušatelj pridobil: • sposobnosti formuliranja problema, • sposobnosti samostojnega iskanja ustrezne literature, • sposobnosti obravnavanja problema v praksi, • sposobnosti iskanja kvantitativnih rešitev in utemeljevanja ustreznosti rešitev, • sposobnosti predstavitve rezultatov svojega dela Uporaba Znanje in pridobljene veščine bo magistrant lahko uporabil pri opravljanju poklica. Refleksija Povezovanje vseh pridobljenih teoretičnih znanj z reševanjem problemov na področju kemije ter kritični pogled na uporabnost teh znanj. Prenosljive spretnosti Pri delu bo magistrant pridobil znanja o metodah reševanja kompleksnih problemov, o načinu prezentacije teh znanj v pisani in govorjeni obliki, povezani z ostalimi metodami posredovanja raziskav, ugotovitev itd.	Knowledge and Comprehension Ability to formulate the problem and research literature independently; Ability of independent problem managing in practice; Ability of independent problem solving and argumentation of the solution; Ability to present results of research work. Application Acquired skills are necessary for professional work. Analysis Integration of knowledge from different topics from chemistry and supporting sciences; Development of a critical view on the knowledge applicability. Skill-transference Ability Ability of solving complex problems using different methods; Ability of presenting research results in a written and oral form.

Metode poučevanja in učenja:	Learning and teaching methods:
Individualno delo z mentorjem in samostojno študijsko in raziskovalno delo.	Independent research work supervised by the mentor/supervisor.

Načini ocenjevanja:	Delež/Weight	Assessment:
Komisija za oceno in zagovor magistrskega dela oceni magistrsko delo in zagovor.	100,00 %	Master thesis and its presentation are graded by the thesis commitee.

Ocenjevalna lestvica:	Grading system:

Reference nosilca/Lecturer's references:

VODIKOVE TEHNOLOGIJE IN NJIHOV INŽENIRING

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Vodikove tehnologije in njihov inženiring
Course title:	Hydrogen Technologies and Their Engineering
Članica nosilka/UL Member:	UL FKKT

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Kemija, druga stopnja, magistrski (od študijskega leta 2025/2026 dalje)	Materiali za shranjevanje in pretvorbo energije (smer)	2. letnik	1. semester	obvezni

Univerzitetna koda predmeta/University course code:	0644106
Koda učne enote na članici/UL Member course code:	TU19UN

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
30	15	30 LV			75	6

Nosilec predmeta/Lecturer:	izr. prof. dr. Boštjan Genorio
Vrsta predmeta/Course type:	obvezni/Mandatory
Jeziki/Languages:	Predavanja/Lectures: Angleščina; Vaje/Tutorial: Angleščina

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	Prerequisites:
Predmet lahko izberejo tudi tuji študenti na mednarodni izmenjavi na UL, ki morajo imeti podpisan učni sporazum (LA) med UL FKKT in drugimi tujimi izobraževalnimi ustanovami.	The subject can be attended by international exchange students that have a signed learning agreement between UL FKKT and another foreign educational institution.

Vsebina:	Content (Syllabus outline):
Predmet celovito obravnava vodikove tehnologije, s poudarkom na vodikovih gorivnih celicah in njihovi uporabi. Študenti bodo pridobili poglobljeno znanje o različnih vrstah gorivnih celic, procesih izdelave elektrod in celic za gorivne celice, formulaciji elektrod, tehnikah elektrokemijske karakterizacije in elektrokemijskih napravah za pridobivanje vodika. Poudarek je na razumevanju načel, dizajniranju in praktičnih aplikacij vodikovih tehnologij v različnih industrijah. Specifične teme: *Uvod v vodikove tehnologije* •Pregled vodika kot nosilca energije.	This course provides an in-depth study of hydrogen technologies, focusing on hydrogen fuel cells and their technical applications. Students will gain comprehensive knowledge of various types of fuel cells, fuel cell electrode and cell fabrication processes, electrode formulation, electrochemical characterization techniques, and electrochemical water-splitting devices. The focus is on understanding the principles, design, and practical applications of hydrogen technologies in various industries. Specific topics covered: *Introduction to Hydrogen Technologies* •Overview of hydrogen as an energy carrier.

• Zgodovinski razvoj in trenutni status vodikovih tehnologij. •Pomen in uporaba vodikovih gorivnih celic. *Vodikove gorivne celice* •Razvrstitev gorivnih celic glede na temperaturo: nizka, srednja in visoka. •Načela dela in pogoji delovanja posamezne vrste. •Učinkovitost, prednosti in omejitve vodikovih gorivnih celic. *Postopki izdelave elektrod in celic gorivnih celic* •Izbira in priprava materialov za elektrode in elektrolitske membrane. • Tehnike izdelave: sitotisk, brizganje, brizganje itd. •Ukrepi za nadzor kakovosti in testiranje med proizvodnjo. *Formulacija elektrode* •Sestava in lastnosti elektrodnih materialov (katalizatorji, nosilci itd.). •Optimizacija formulacije elektrod za izboljšano učinkovitost in vzdržljivost. •Vloga oblikovanja elektrod pri izboljšanju učinkovitosti gorivnih celic. *Elektrokemijska karakterizacija* • Tehnike za karakterizacijo delovanja gorivnih celic: polarizacijske krivulje, elektrokemična impedančna spektroskopija (EIS), ciklična voltametrija itd. •Interpretacija eksperimentalnih podatkov in korelacija z lastnostmi elektrode/elektrolita. •Metode za oceno mehanizmov razgradnje in trajnosti gorivnih celic. *Elektrolizerji* •Principi elektrolize vode za proizvodnjo vodika. •Vrste elektrolizatorjev: alkalne, PEM, celice za elektrolizo s trdnim oksidom (SOEC). •Zasnova, učinkovitost in izzivi pri elektrokemičnem cepljenju vode. *Vodikova infrastruktura* •Proizvodne zmogljivosti •Shranjevanje •Distribucijski sistemi •Postaje za točenje goriva	•Historical development and current status of hydrogen technologies. •Importance and applications of hydrogen fuel cells. *Hydrogen Fuel Cells* •Classification of fuel cells based on temperature: low, intermediate, and high. •Working principles and operating conditions of each type. •Efficiency, advantages, and limitations of hydrogen fuel cells. *Manufacturing Processes of Fuel Cell Electrodes and Cells* •Materials selection and preparation for electrodes and electrolyte membranes. •Fabrication techniques: screen printing, spraying, sputtering, etc. •Quality control measures and testing during manufacturing. *Electrode Formulation* •Composition and properties of electrode materials (catalysts, supports, etc.). •Optimization of electrode formulation for enhanced performance and durability. •Role of electrode design in improving fuel cell efficiency. *Electrochemical Characterization* •Techniques for characterizing fuel cell performance: polarization curves, electrochemical impedance spectroscopy (EIS), cyclic voltammetry, etc. •Interpretation of experimental data and correlation with electrode/electrolyte properties. •Methods for assessing degradation mechanisms and durability of fuel cells. *Electrochemical Water Splitting Devices* •Principles of water electrolysis for hydrogen production. •Types of electrolyzers: alkaline, PEM, solid oxide electrolysis cells (SOEC). •Design considerations, efficiency, and challenges in electrochemical water splitting. *Hydrogen infrastructure* •Production facilities •Storage •Distribution systems •Refuelling stations

Temeljna literatura in viri/Readings:

1.) Introduction to Hydrogen Technology; Authors: K. S. V. Santhanam, Roman J. Press, Massoud J. Miri, Alla V. Bailey, Gerald A. Takacs; Publisher: Wiley; 2018

2.) Hydrogen and fuel cells: emerging technologies and applications hydrogen and fuel cells emerging technologies and applications; Author: Bent Sørensen; Publisher: Elsevier; 2012

3.) Electrochemical Methods: Fundamentals and Applications; Authors: Allen J. Bard and Larry R. Faulkner; Publisher: Wiley; 2001

4.) Green Hydrogen in Power Systems; Author: Vahid Vahidinasab; Publisher: Springer; 2024

5.) Fuel Cells and Hydrogen: From Fundamentals to Applied Research; Authors: Viktor Hacker, Shigenori Mitsushima; Publisher: Elsevier; 2018

6.) Hydrogen Storage Materials: The Characterization Techniques, Properties, and Applications Author: Darren P. Broom Publisher: Springer; 2011

Cilji in kompetence:	**Objectives and competences:**
Cilj predmeta; študentje bodo sposobni: razumeti osnove vodikovih tehnologij in študentom omogočiti celovito razumevanje lastnosti, proizvodnih metod, shranjevanja in uporabe vodika kot nosilca energije. raziskati raznoliko paleto aplikacij vodikovih tehnologij v različnih sektorjih, kot so transport, industrija in proizvodnja električne energije. razumeti okoljske posledice vodikovih tehnologij, vključno z njihovim potencialom za zmanjšanje emisij toplogrednih plinov in prispevanje k ciljem trajnostnega razvoja. upoštevati varnostne pomisleke, povezane z rokovanjem, shranjevanjem in uporabo vodika, kot tudi regulativne okvire, ki urejajo njegovo uporabo. razumeti ekonomsko upravičenost in ekonomsko izvedljivosti komercialnega potenciala vodikovih tehnologij ob upoštevanju dejavnikov, kot so proizvodni stroški n infrastrukturne zahteve. delati na področju inovacij in raziskav pri razvoju novih vodikovih tehnologij in pri raziskovanju novih konceptov in rešitev za obstoječe izzive. *Kompetence:* Pridobljene tehnične veščine pri načrtovanju, delovanju in vzdrževanju sistemov za proizvodnjo, shranjevanje in uporabo vodika, vključno s poznavanjem ustreznih inženirskih principov in tehnologij. Pridobljene sposobnosti reševanja problemov in prepoznavanje ter reševanje tehničnih izzivov, povezanih z vodikovimi tehnologijami, z uporabo analitičnega razmišljanja in inovativnih tehnik reševanja problemov. Pridobljeno interdisciplinarno znanje o razumevanju interdisciplinarne narave vodikovih tehnologij, ki vključuje vpoglede s področij, kot so kemija, fizika, vede o materialih in okoljski inženiring. Pridobljene mehke veščine z ustno in pisno komunikacijo kompleksnih tehničnih konceptov, povezanih z vodikovimi tehnologijami, različnim občinstvom, vključno z vrstniki, zainteresiranimi stranmi in splošno javnostjo.	*Objectives* students will be able to: understand hydrogen technology fundamentals and provide students with a comprehensive understanding of the properties, production methods, storage, and utilization of hydrogen as an energy carrier. explore the diverse range of applications of hydrogen technologies across different sectors such as transportation, industry, and power generation. understand the environmental implications of hydrogen technologies, including their potential to mitigate greenhouse gas emissions and contribute to sustainable development goals. consider safety considerations associated with handling, storing, and using hydrogen, as well as the regulatory frameworks governing its deployment. understand economic viability and the economic feasibility of commercial potential of hydrogen technologies, considering factors such as production costs and infrastructure requirements. work on innovation and research in the development of new hydrogen technologies, and to explore novel concepts and solutions to existing challenges. *Competences:* Obtain technical skills in the design, operation, and maintenance of hydrogen production, storage, and utilization systems, including knowledge of relevant engineering principles and technologies. Obtain problem-solving abilities to identify and address technical challenges associated with hydrogen technologies, employing analytical thinking and innovative problem-solving techniques. Obtain interdisciplinary knowledge of understanding of the interdisciplinary nature of hydrogen technologies, integrating insights from fields such as chemistry, physics, materials science, and environmental engineering. Obtain soft skills through communication of complex technical concepts related to hydrogen technologies, both orally and in writing, to diverse audiences including peers, stakeholders, and the general public.

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanje in razumevanje: tehnologij gorivnih celic in elektrolizatorjev, vključno z vodikovo infrastrukturo ter varnostnimi in okoljskimi vidiki. kritičnega mišljenja in veščin reševanja problemov, ki bodo učinkovito posredovani zainteresirani javnosti. Pridobljeno znanje bodo lahko uporabili pri reševanju problemov za naslednjo generacijo naprav za	Knowledge and understanding: of fuel cell technologies and electrolyzers including hydrogen infrastructure and safety and environmental considerations. of critical thinking and problem-solving skills which will be effectively communicated. They will be able to apply the acquired knowledge to problem-solving for the next-generation energy

shranjevanje in pretvorbo energije v akademskih krogih in evropski industriji. Svoje znanje bodo lahko uporabili pri reševanju aktualnih problemov pomembnih alternativnih tehnologij prihodnosti.	storage and conversion devices in academia and European industry. They will be able to apply their knowledge to solving current problems of important alternative technologies of the future.

Metode poučevanja in učenja:	**Learning and teaching methods:**
Predavanja, seminarji in laboratorijsko delo.	Lectures, seminars and labwork.

Načini ocenjevanja:	**Delež/Weight**	**Assessment:**
Laboratorijske vaje	30,00 %	Labwork
Analiza članka	10,00 %	Article analysis
Raziskovalni predlog (pisni del)	40,00 %	Research proposal (written part)
Raziskovalni predlog (predstavitev, diskusija)	20,00 %	Research proposal (presentation, discussion)

Ocenjevalna lestvica:	**Grading system:**
5 - 10, pri čemer velja, da je pozitivna ocena od 6 - 10	5 - 10, a student passes the exam if he is graded from 6 to 10

Reference nosilca/Lecturer's references:

(1) **Genorio, B.**; Strmcnik, D.; Subbaraman, R.; Tripkovic, D.; Karapetrov, G.; Stamenkovic, V. R.; Pejovnik, S.; Marković, N. M. Selective Catalysts for the Hydrogen Oxidation and Oxygen Reduction Reactions by Patterning of Platinum with Calix[4]Arene Molecules. *Nat. Mater.* **2010**, *9* (12), 998–1003. https://doi.org/10.1038/nmat2883.

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