UČNI NAČRT

UČNI NAČRT PREDMETA / COURSE SYLLABUS	
Predmet:	Strukturna karakterizacija materialov
Course title:	Structural characterization of materials

Študijski program in stopnja Study programme and level	Študijska smer Study field	Letnik Academic year	Semester Semester
MŠP Kemija, 2. stopnja	Materiali za shranjevanje in pretvorbo energije	2	3
USP Chemistry, 2nd Cycle	Materials for Energy Storage and Conversion	2nd	3rd

Vrsta predmeta / Course type	Obvezni / Mandatory
Univerzitetna koda predmeta / University course code:	

Predavanja Lectures	Seminar Seminar	Vaje Tutorial	Klinične vaje work	Druge oblike študija	Samost. delo Individ. work	ECTS
20	10	20			50	4

Nosilec predmeta / Lecturer:	prof. dr. Anton Meden / Dr. Anton Meden, Full Professor

Jeziki / Languages:	**Predavanja / Lectures:**	**Angleški / English**
	Vaje / Tutorial:	**Angleški / English**

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

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.

Prerequisites:

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:

Kristalne strukture: amorfno in kristalinično stanje, primeri struktur.

Simetrija: ugotavljanje simetrije na primerih struktur, simetrijski elementi, točkovne skupine, prostorske skupine, kristalni sistemi, osnovna celica, kristalne mreže.

Difrakcija: radiacija in njena interakcija s kristali, Braggov zakon, difrakcija na monokristalu in prahu.

Identifikacija in kvantifikacija faz: osnove metode, uporaba obstoječega znanja (zbirke podatkov), primer iskalnega programa, osnove in primeri kvantitativne fazne analize.

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.

Osnove fizike trdnega stanja in teoretske kemije: zveza med lastnostmi na atomski skali in makroskopskimi

Content (Syllabus outline):

Crystal structures: amorphous and crystalline state, examples of structures.

Symmetry: exploring symmetry in the example structures, symmetry elements, point groups, space groups, crystal systems, unit cell, crystal lattices.

Diffraction: radiation and its interaction with crystals, Bragg law, single crystal and powder diffraction.

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.

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.

Basics in Solid State Physics and

lastnostmi z nekaj primeri.	**Theoretical Chemistry:** relation between atomic-scale properties and large-scale properties with some examples.

Temeljni literatura in viri / Readings:

V. K. Pecharsky and P. Z. Zavalij: Fundamentals of Powder Diffracton and Structural Characterization of Materials, Springer, ISBN 0-387-24147-7, New York, USA, 2005.

Cilji in kompetence:	**Objectives and competences:**
Cilji: Razumevanje strukturnih principov v trdninah, 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, 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 načinov njene uporabe. Uporaba Uporaba praškovne difrakcije za temeljno karakterizacijo materialov. Uporaba orodij in podatkov iz kristalografskih podatkovnih zbirk.	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 materials. The application of tools and data from crystallographic databases.

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.	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 (v %) / Weight (in %)	**Assessment:**
Ustni izpit, ki vključuje reševanje praktičnega problema	**100%**	Oral exam including solution of a practical problem

Reference nosilca / Lecturer's references:

1.) STARE, Jernej, MEDEN, Anton, HADŽI, Dušan. Structure determination by joint effort of X-ray powder diffraction and quantum calculations : crystal structure and short hydrogen bonding in pentadecafluorooctanoic acid hydrate. *Croatica chemica acta*, ISSN 0011-1643. [Print ed.], 2018, vol. 91, no. 2, str. 209-220.
2.) MEDEN, Anton, RADOSAVLJEVIĆ EVANS, Ivana. Structure determination from powder diffraction data : past, present and future challenges. *Crystal research and technology*, ISSN 1521-4079, 2015, vol. 50, issue 9-10, str. 747-758.
3.) POČKAJ, Marta, MEDEN, Anton, ZABUKOVEC LOGAR, Nataša, RANGUS, Mojca, MALI, Gregor, LEZCANO-GONZÁLEZ, Inés, BEALE, Andrew M., GOLOBIČ, Amalija. Structural investigations in pure-silica and Al-ZSM-12 with MTEA or TEA cations. *Microporous and mesoporous materials : zeolites, clays, carbons and related materials*, ISSN 1387-1811, Jun. 2018, vol. 263, str. 236-242.

UČNI NAČRT

UČNI NAČRT PREDMETA / COURSE SYLLABUS	
Predmet:	Termična, sestavna in morfološka analiza materialov
Course title:	Thermal, textural and morphological analysis of materials

Študijski program in stopnja **Study programme and level**	**Študijska smer** **Study field**	**Letnik** **Academic year**	**Semester** **Semester**
MŠP Kemija, 2. stopnja	**Materiali za shranjevanje in pretvorbo energije**	**2**	**3**
USP Chemistry, 2nd Cycle	**Materials for Energy Storage and Conversion**	**2nd**	**3rd**

Vrsta predmeta / Course type	Obvezni / Mandatory
Univerzitetna koda predmeta / University course code:	

Predavanja **Lectures**	**Seminar** **Seminar**	**Vaje** **Tutorial**	**Klinične vaje** **work**	**Druge oblike študija**	**Samost. delo** **Individ. work**	**ECTS**
20	**10**	**15**	**/**	**/**	**45**	**3**

Nosilec predmeta / Lecturer:	doc. dr. Boštjan Genorio & prof. dr. Marjan Marinšek / dr. Boštjan Genorio, Assistant Professor & dr. Marjan Marinšek, Associate Professor

Jeziki / Languages:	**Predavanja / Lectures:**	**Angleški / English**
	Vaje /	**Angleški / English**

Tutorial:

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):**
1. Metode določevanja velikosti in porazdelitve velikosti delcev: definicija disperznega sistema, problem določevanja velikosti nepravilnih delcev, meritve velikosti delcev in porazdelitve velikosti delcev, določevanje faktorjev oblike, definicija specifične površine in meritev specifične površine disperznega sistema, definicija poroznosti in merjenje poroznosti disperznega sistema. 2. Termoanalizne tehnike: definicija koncepta termične analize, termogravimetrija (TG), 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 za vzorec 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): optična in elektronska (SEM, TEM) mikroskopija,EDS in WDS spektroskopija, elektronska difrakcija v TEM mikroskopiji,	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 (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, scanning probe): optical and electron microscopy (SEM, TEM), EDS and WDS spectroscopy, electron

mikroskopija na atomsko silo (AFM), vrstična tunelska mikroskopija (STM), primeri mikrostrukturne kvantitativne analize različnih materialov.	diffraction in TEM microscopy, atomic force microscopy (AFM), scanning tunneling microscopy (STM), examples of microstructure quantitative analysis of materials.

Temeljni 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 analiznih tehnik s področja ved o materialih • Znajo uporabiti različne analizne tehnike za analitiko materialov s področja shranjevanja in konverzije energije • Razumejo omejitve pri uporabi različnih analiznih tehnik • Znajo samostojno delati z izbrano sofisticirano analizno opremo.	At the end of this course students should be able to: • Understand the principles of the various analytical techniques applied in Material science. • Apply individual analytical techniques for novel materials related to energy storage and conversion applications. • Understand the limitations of individual analytical techniques. • Be able to perform specific measurements on specific analytical apparatus.

Predvideni študijski rezultati:	**Intended learning outcomes:**
<u>Znanje in razumevanje</u> Študentje spoznajo različne analizne tehnike, ki omogočajo poglobljeno analizo različnih materialov.	<u>Knowledge and Comprehension</u> Students learn about various analytical techniques that enable thorough characterization of materials.

Uporaba	Application
Pridobljeno znanje se lahko uporabi za reševanje problemov, povezanih z razvojem naslednje generacije materialov za shranjevanje in konverzijo energije na akademskem in industrijskem nivoju. 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.	Acquired knowledge will be used in problem solving 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.

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

Načini ocenjevanja:	Delež (v %) / Weight (in %)	**Assessment:**
Laboratorijsko delo	**30%**	Labwork
Pisni izpit	**70%**	Written exam

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.

(2) Genorio, B.; Lu, W.; Dimiev, A. M.; Zhu, Y.; Raji, A.-R. O.; Novosel, B.; Alemany, L. B.; Tour, J. M. In Situ Intercalation Replacement and Selective Functionalization of Graphene Nanoribbon Stacks. *ACS Nano* **2012**, *6* (5), 4231–4240. https://doi.org/10.1021/nn300757t.

(3) Vizintin, A.; Lozinšek, M.; Chellappan, R. K.; Foix, D.; Krajnc, A.; Mali, G.; Drazic, G.; Genorio, B.; Dedryvère, R.; Dominko, R. Fluorinated Reduced Graphene Oxide as an Interlayer in Li–S Batteries. *Chem. Mater.* **2015**, *27* (20), 7070–7081. https://doi.org/10.1021/acs.chemmater.5b02906.

(4) Strmcnik, D.; Lopes, P. P.; Genorio, B.; Stamenkovic, V. R.; Markovic, N. M. Design Principles for Hydrogen Evolution Reaction Catalyst Materials. *Nano Energy* **2016**, *29*, 29–36. https://doi.org/10.1016/j.nanoen.2016.04.017.

(5) Staszak-Jirkovský, J.; Malliakas, C. D. D.; Lopes, P. P. P.; Danilovic, N.; Kota, S. S. S.; Chang, K.-C.; Genorio, B.; Strmcnik, D.; Stamenkovic, V. R. R.; Kanatzidis, M. G.; et al. Design of Active and Stable Co-Mo-Sx Chalcogels as PH-Universal Catalysts for the Hydrogen Evolution Reaction. *Nat. Mater.* **2016**, *15* (November), 197–203. https://doi.org/10.1038/nmat4481.

(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.* **2018**, *8* (1), 5819. https://doi.org/10.1038/s41598-018-23991-2.

(7) SKALAR, Tina, ZUPAN, Klementina, MARINŠEK, Marjan. Microstructure tailoring of combustion-derived Ni-GDC and Ni-SDC composites as anode materials for intermediate temperature solid oxide fuel cells. *Journal of the Australian Ceramic Society*, ISSN 2510-1579, Mar. 2019, vol. 55, iss. 1, str. 123-133, ilustr. https://link.springer.com/article/10.1007/s41779-018-0218-z.

(8) MARQUES, Susana, MESTRE, Ana S., MACHUQUEIRO, Miguel, ŽGAJNAR GOTVAJN, Andreja, MARINŠEK, Marjan, CARVALHO, Ana Paula. Apple tree branches derived activated carbons for the removal of ß-blocker atenolol. *Chemical engineering journal*, ISSN 1385-8947. [Print ed.], Aug. 2018, vol. 345, str. 669-678, ilustr. https://www.sciencedirect.com/science/article/pii/S1385894718300925.

(9) ŠTUKOVNIK, Petra, BOKAN-BOSILJKOV, Violeta, MARINŠEK, Marjan. Microstructural changes in cement mortar due to an alkali carbonate reaction = Spremembe mikrostrukture cementne malte zaradi alkalno karbonatne reakcije. *Materiali in tehnologije*, ISSN 1580-2949. [Tiskana izd.], 2019, letn. 53, št. 3, str. 425-432, ilustr. http://mit.imt.si/Revija/izvodi/mit193/stukovnik.pdf

(10) PORI, Maja, ARČON, Iztok, LAŠIČ JURKOVIĆ, Damjan, MARINŠEK, Marjan, DRAŽIĆ, Goran, LIKOZAR, Blaž, CRNJAK OREL, Zorica. Synthesis of a Cu/ZnO nanocomposite by electroless plating for the catalytic conversion of CO2 to methanol. *Catalysis letters*, ISSN 1011-372X, May 2019, vol. 149, iss. 5, str. 1427-1439, ilustr. https://link.springer.com/article/10.1007/s10562-019-02717-7

UČNI NAČRT

UČNI NAČRT PREDMETA / COURSE SYLLABUS	
Predmet:	Sodobne tehnike sinteze nanomaterialov
Course title:	Modern techniques for the synthesis of nanomaterials

Študijski program in stopnja Study programme and level	Študijska smer Study field	Letnik Academic year	Semester Semester
MAG Kemija, 2. stopnja	Materiali za shranjevanje in pretvorbo energije	2.	3.
USP Chemistry, 2nd Cycle	Materials for Energy Storage and Conversion	2nd	3rd

Vrsta predmeta / Course type	Obvezni / Mandatory
Univerzitetna koda predmeta / University course code:	

Predavanja Lectures	Seminar Seminar	Vaje Tutorial	Klinične vaje work	Druge oblike študija	Samost. delo Individ. work	ECTS
30	/	15	/	/	45	3

Nosilec predmeta / Lecturer:	prof. dr. Robert Dominko/ dr. Robert Dominko, Full Professor

Jeziki / Languages:	**Predavanja / Lectures:**	**angleški/ English**
	Vaje / Tutorial:	**angleški/ English**

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

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.

Prerequisites:

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:

- 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 elektrokemičnih celicah
- Prednosti in slabosti uporabe nanomaterialov
- Kritična ocena praktične uporabe nanomaterialov

Content (Syllabus outline):

- 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

Temeljni 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 literature (20%)

Cilji in kompetence:

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 prednostih in slabostih nanomaterialov pri shranjevanju in pretvorbi energije.

Objectives and competences:

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 emphasize is on the characterization techniques and advantages and disadvantages of nanomaterials in energy storage and conversion.

Predvideni študijski rezultati:

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.

Intended learning outcomes:

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

Prenosljive spretnosti: Pridobljeno znanje je neposredno prenosljivo na druga znanstvena področja, kot so kemija, kemijsko inženirstvo in elektrotehnika.	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 preučevanje literature	Lectures, labwork and literature study

Načini ocenjevanja:	Delež (v %) / Weight (in %)	**Assessment:**
Izpit (pisni)	**60%**	Exam (Written)
Vaje	**40%**	Labwork

Reference nosilca / Lecturer's references:

(1) Dominko, R; Bele, M; Gaberscek, M; Remskar, M; Hanzel, D; Goupil, JM; Pejovnik, S; Jamnik, J, J., Porous olivine composites synthesized by sol-gel technique, Power Sources, 153, 274-280 (2006)

(2) Dominko, R; Bele, M; Gaberscek, M; Remskar, M; Hanzel, D; Pejovnik, S; Jamnik, J, Impact of the carbon coating thickness on the electrochemical performance of $LiFePO_4$/C composites,J. Eletrochem. Soc., 152, A607-A610 (2005).

(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 $Bi_4B_2O_9$ 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 Li_2MnSiO_4 and Li_2FeSiO_4 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).

UČNI NAČRT

UČNI NAČRT PREDMETA / COURSE SYLLABUS	
Predmet:	Elektrokemija naprav za shranjevanje energije
Course title:	Electrochemical Energy Storage

Študijski program in stopnja Study programme and level	Študijska smer Study field	Letnik Academic year	Semester Semester
MŠP Kemija, 2. stopnja	**Materiali za shranjevanje in pretvorbo energije**	**2**	**3**
USP Chemistry, 2nd Cycle	**Materials for Energy Storage and Conversion**	**2nd**	**3rd**

Vrsta predmeta / Course type	Obvezni / Mandatory
Univerzitetna koda predmeta / University course code:	

Predavanja Lectures	Seminar Seminar	Vaje Tutorial	Klinične vaje work	Druge oblike študija	Samost. delo Individ. work	ECTS
30	**15**	**15**			**60**	**4**

Nosilec predmeta / Lecturer:	prof. dr. Miran Gaberšček / Dr. Miran Gaberšček, Full Professor

Jeziki / Languages:	**Predavanja / Lectures:**	**Angleški / English**
	Vaje / Tutorial:	**Angleški / English**

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

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.

Prerequisites:

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:

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, 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.

Content (Syllabus outline):

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 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.

Baterijske tehnologije

Zgodovinski razvoj 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, post litij-ionski sistemi). Prednosti in slabosti različnih sistemov. Predstavitev in podrobnejša obravnava tipičnih odprtih vprašanj, povezanih s sodobnimi baterijskimi sistemi, predstavitev usmeritev za prihodnost.

Proizvodnje vodika, njegov transport in klasično shranjevanje

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. Primerjava tehnologij z vidika zrelosti, učinkovitosti, predstavitev odprtih vprašanj. Obravnava klasičnih tehnologij za shranjevanje vodika: shranjevanje plinastega vodika, utekočinjanje vodika in njegovo shranjevanje. Transportne tehnologije, varnostni vidiki.

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 $NaAlH_4$, $LiAlH_4$, $LiBH_4$ ipd.). Vpliv nanostrukturiranosti na različne vidike shranjevanja (kapaciteta, kinetika, ciklabilnost, temperatura sproščanja,

Detailed presentation of the most important systems (lead-acid, nickel-cadmium, nickel-metal hydride, lithium ion, post-lithium ion systems etc.). Advantages and disadvantages of various systems. Presentation of open questions in modern systems, discussion of possible solution and research directions.

Hydrogen production, transport and classical storage

Introduction of hydrogen as important future energy carrier. Presentation of emerging hydrogen production technologies: electrolysis, photolysis, thermolysis, production from biomass, thermochemical cycles. 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.

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 $NaAlH_4$, $LiAlH_4$, $LiBH_4$ etc.). The impact of nanostructurization on performance requirements for storage (capacity, kinetics, cyclability, cost, release temperature).

cena itd.).	

Temeljni 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:

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 njihovih lastnosti

Kompetence:

Splošne kompetence: razumevanje osnovnih principov delovanja najpomembnejših obstoječih sistemov za shranjevanje energije. Sposobnost kvalitativne in kvantitativne primerjave različnih sistemov za shranjevanje energije. Poseben poudarek je na razumevanju delovanja in lastnosti baterij ter

Objectives and competences:

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

kovinskih hidridov. Pridobljena splošna znanja so nato usmerjena v razumevanje in uposabljanje za raziskovalno delo na področju baterij in kovinskih hidridov.	laboratory work in the field of electrochemistry.

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanje in razumevanje Študenti pridobijo temeljna znanja, potrebna za razumevanje delovanja naprav za shranjevanje energije. Podrobno razumejo delovanje sodobnih baterijskih naprav in mehanizme shranjevanja energije v obliki kovinskih hidridov. Sposobni so 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. Študenti se na teh področjih usposobijo za samostojno raziskovalno delo in spoznajo načine prenosa in uporabe teoretskih zakonitosti v praksi. Refleksija Pridobljeno teoretično znanje omogoča študentom poglobljen vpogled v osnovne koncepte in zakonitosti na področju shranjevanja energije. Dodatno študenti pridobijo veščine prenosa osnovnih znanj na izbrane praktične primere, kot so baterije, kovinski hidridi in podobno. Vsebina in izvedba predmeta predstavlja dobro osnovo za kasnejše aktivno in samostojno udejstvovanje na področju raziskav in uporabe znanj s področja shranjevanja energije v praksi. Prenosljive spretnosti	Knowledge and Comprehension Students acquire base knowledge needed for understanding operation of devices for energy storage. They understand in detail the operation of modern battery systems and mechanisms of energy storage in metal hydrides. They are 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. Students become qualified for independent research in the field and get 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 students acquire the ability to apply knowledge base into selected practical examples. The curriculum represents a solid background for later active and 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 Students acquire experimental skills in the field of energy storage devices, master the use of scientific and professional literature and develop

Pridobijo veščine na področju konceptov in naprav za shranjevanje energije, znajo uporabljati znanstveno in strokovno literaturo ter pravilno predstaviti in razlagati merske rezultate. Pridobijo znanja, potrebna za projektno in timsko delo.	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 (v %) / Weight (in %)	**Assessment:**
Pisni izpit	**100%**	Written exam

Reference nosilca / Lecturer's references:

1. DRVARIČ TALIAN, Sara, MOŠKON, Jože, DOMINKO, Robert, GABERŠČEK, Miran. Reactivity and diffusivity of Li polysulfides : a fundamental study using impedance spectroscopy. *ACS applied materials & interfaces*, ISSN 1944-8244. 2017, vol. 9, no. 35, str. 29760-29770.
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. MOŠKON, Jože, PIVKO, Maja, JERMAN, Ivan, TCHERNYCHOVA, Elena, ZABUKOVEC LOGAR, Nataša, ZORKO, Milena, ŠELIH, Vid Simon, DOMINKO, Robert, GABERŠČEK, Miran. Cycling stability and degradation mechanism of $LiMnPO_4$ based electrodes. *Journal of power sources*, 2016, vol. 303, str. 97-108.
4. 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.

5. PIRNAT, Klemen, DOMINKO, Robert, CERC KOROŠEC, Romana, MALI, Gregor, GENORIO, Boštjan, GABERŠČEK, Miran. Electrochemically stabilised quinone based electrode composites for Li-ion batteries. *Journal of power sources*, 2012, vol. 199, str. 308-314.

UČNI NAČRT

UČNI NAČRT PREDMETA / COURSE SYLLABUS	
Predmet:	Mehke veščine in strokovni razvoj
Course title:	Soft skills and professional development

Študijski program in stopnja Study programme and level	Študijska smer Study field	Letnik Academic year	Semester Semester
MAG Kemija, 2. stopnja	Materiali za shranjevanje in pretvorbo energije	2.	3.
USP Chemistry, 2nd Cycle	Materials for Energy Storage and Conversion	2st	3rd

Vrsta predmeta / Course type	Obvezni / Mandatory
Univerzitetna koda predmeta / University course code:	

Predavanja Lectures	Seminar Seminar	Vaje Tutorial	Klinične vaje work	Druge oblike študija	Samost. delo Individ. work	ECTS
30	30	/	/	/	60	4

Nosilec predmeta / Lecturer:	prof. dr. Robert Dominko/ dr. Robert Dominko, Full Professor

Jeziki / Languages:	**Predavanja / Lectures:**	**angleški/ English**
	Vaje / Tutorial:	**angleški/ English**

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

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.

Prerequisites:

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:

- Predstavitev rezultatov
- Poročanje o rezultatih
- Predstavitvena retorika
- Profesionalni razvoj
- 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
- Industrijski projekti

Content (Syllabus outline):

- Results presentation
- Results reporting
- Presentation rhetoric
- Professional development
- 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
- Project coordination and reporting
- Industrial projects

Temeljni literatura in viri / Readings:

1.) 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) (20%)
2.) Key competences for lifelong learning; EU Commission document; 2019 ISBN: 978-92-76-00475-2 (20%)
3.) Najnovejša literatura (ključne beside: kako napisati znanstveno poročilo, … (10%)
4.) https://ec.europa.eu/research/participants/docs/h2020-funding-guide/grants/applying-for-funding/submit-proposals_en.htm (20%)

5.) L. Bently and B. Sherman, Intellectual Property Law, Oxford University Press; 3rd edition (November 15, 2008), ISBN-13: 978-0199292042 (20%)
6.) Najnovejša literature (ključne beside: kako napisati uspešen projekt, kako pripraviti patentno vlogo, … (10%)

Cilji in kompetence:

Ob koncu tega predmeta so študentje sposobni:

- strukturiranja rezultatov v izčrpno poročilo / predlog članka / magistrsko delo;
- poročanja o rezultatih pred različnimi skupnostmi (strokovna, nestrokovna ali laična javnost);
- priprave poročil in predstavitve, ki je razumljiva, brez balasta, gladka in logična;
- študenti bodo dobili vpogled v strokovni razvoj s poudarkom na možnostih doktorskega študija in potencialnem podoktorskem študiju.
- iskanja literature z različnimi iskalniki;
- pisanja projektnih predlogov;
- ustrezne zaščite intelektualne lastnine;
- priprave patentne prijave;
- predloga projekta za industrijskega partnerja.

Objectives and competences:

At the end of this course students are able to:

- structure results into the comprehensive report/manuscript/thesis;
- report results in front of different communities (professional, public or lay community);
- preparation of the reports and presentation which is understandable, without ballast, smooth and logical;
- students will get insights about professional development, with a focus on possibilities in the PhD study and potential postdoctoral research studies.
- search for the literature by using different search engines;
- write a proposal for governmental founds;
- apply proper protection of intellectual property;
- draft a patent application;
- convince an industrial partner to invest in their research.

Predvideni študijski rezultati:

Znanje in razumevanje:

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.

Študenti se bodo naučili, kako iskati literaturo, katere iskalnike je mogoče uporabiti, kako

Intended learning outcomes:

Knowledge and Comprehension

Students learn how to present results in the understandable way, how to write reports, theses, manuscripts, policy of publishers. Students get some insights about possibility of carrier development after master study in academia and private sector.

Students will learn how to search for the literature, which search engines can be used,

razvrstiti raziskovalno literaturo in kako prepoznati zanesljive rezultate. Izvedeli bodo o različnih možnostih za zaščito intelektualne lastnine, kako izpolniti patentne prijave, kaj je pomembno in kakšne so razlike med različnimi možnostmi. Zadnji del predmeta bo namenjen pisanju projektov: individualni – različne štipendije in obsežni projekti. Kako delati v velikih konzorcijih in kako dobiti neposredne pogodbe z industrijo. <u>Uporaba:</u> Pridobljeno znanje bo uporabljeno pri kariernem in osebnem razvoju. <u>Refleksija:</u> Pridobljeno znanje je orodje, ki študentom pomaga pri njihovem poklicnem in osebnem razvoju. <u>Prenosljive spretnosti:</u> Pridobljeno znanje je zelo koristno v prihodnjih študijah, razvoju nosilcev in v osebnem življenju.	how to classify research literature and how to recognize trustable results. 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. Last part of the course will be devoted to writing projects: small – individual fellowships and large-scale collaboration projects. How to work in large consortiums and how to get direct contracts with industry. <u>Application</u> Acquired knowledge will be used in carrier and personal development. <u>Analysis</u> The acquired knowledge is a tool that helps students in their personal carrier development. <u>Skill-transference Ability</u> Acquired knowledge is widely useful in future studies, carrier development, and in personal life.

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

Načini ocenjevanja:	Delež (v %) / Weight (in %)	**Assessment:**

Izpit (pisni del)/	**60%**	Research proposal (Written part)
Seminar (prezentacija, diskusija)	**40%**	Research proposal (Presentation, Discussion)

Reference nosilca / Lecturer's references:

(1) A. Vižintin, J. Bitenc, A. Kopač Lautar, K. Pirnat, J. Grdadolnik, J. Stare, A. Randon-Vitanova, R. Dominko, Probing electrochemical reactions in organic cathode materials via in operando infrared spectroscopy. Nature communications, ISSN 2041-1723, Feb. 2018, vol. 9, str. 1-7

(2) Vizintin, A.; Lozinšek, M.; Chellappan, R. K.; Foix, D.; Krajnc, A.; Mali, G.; Drazic, G.; Genorio, B.; Dedryvère, R.; Dominko, R. Fluorinated Reduced Graphene Oxide as an Interlayer in Li–S Batteries. Chem. Mater. 2015, 27 (20), 7070–7081. https://doi.org/10.1021/acs.chemmater.5b02906.

(3) Mccala, E.; Abakumov, A. M.; Saubanere M.; Foix, D.; Berg E. J.; Rousse G.; Doublet M.-L.; Gonbeau D.; NOVÁK P.; VAN Tendeloo G.; Dominko R.; Tarascon J.-M. Visualization of O-O peroxo-like dimers in high-capacity layered oxides for Li-ion batteries. Science, ISSN 0036-8075, Dec. 2015, vol. 350, no. 6267, str. 1516-1521.

(4) Dominko R., Premikanje meja čez obzorja. ilustracija Adriano Janežič. Volkswagen revija, 2016, št. 4, str. 80, ilustr. [COBISS.SI-ID 5912090]

(5) Dominko R., Silicates and titanates as high-energy cathode materials for Li-ion batteries. V: DHAR, Nibir K. (ur.). Energy harvesting and storage : materials, devices,and applications : proceedings of SPIE : 5-6 April 2010, Orlando, Florida, United States, (Proceedings of SPIE, ISSN 0277-786X, vol. 7683). Bellingham: SPIE. 2010, 8 str., ilustr., doi: 10.1117/12.850801.

(6) Dominko R. (intervjuvanec), "Smiselno je raziskovanje materialov, ki pri pridobivanju ne zahtevajo veliko energije." : dr. Robert Dominko. Gea : poljudnoznanstvena revija, ISSN 0353-782X. [Tiskana izd.], feb. 2016, let. 26, str. 40-43, ilustr. [COBISS.SI-ID 512344442]./

(7) Član komisije za inovacije na Kemijskem inštitutu, Ljubljana, Slovenija in konzultant industriji na področju materialov in kemije v prostem času.

(8) 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

(9) 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]

(10) 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]

(11) 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]

(12) 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

UČNI NAČRT

UČNI NAČRT PREDMETA / COURSE SYLLABUS	
Predmet:	Ogljikovi materiali za shranjevanje in konverzijo energije
Course title:	Carbon materials for energy storage and conversion

Študijski program in stopnja **Study programme and level**	**Študijska smer** **Study field**	**Letnik** **Academic year**	**Semester** **Semester**
MŠP Kemija, 2. stopnja	**Materiali za shranjevanje in pretvorbo energije**	**2**	**3**
USP Chemistry, 2nd Cycle	**Materials for Energy Storage and Conversion**	**2nd**	**3rd**

Vrsta predmeta / Course type	Obvezni / Mandatory
Univerzitetna koda predmeta / University course code:	

Predavanja **Lectures**	**Seminar** **Seminar**	**Vaje** **Tutorial**	**Klinične vaje** **work**	**Druge oblike študija**	**Samost. delo** **Individ. work**	**ECTS**
45	**15**	**15**			**75**	**6**

Nosilec predmeta / Lecturer:	doc. dr. Boštjan Genorio / dr. Boštjan Genorio, Assistant Professor

Jeziki / Languages:	**Predavanja / Lectures:**	**Angleški / English**
	Vaje / Tutorial:	**Angleški / English**

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

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.

Prerequisites:

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:

Materiali na osnovi ogljika so nepogrešljivi v sodobnih tehnologijah. Poleg tega je nedavni razvoj ogljikovih nanomaterialov privedel do intenzivnih znanstvenih dejavnosti s ciljem, da se razvije nov razred materialov za nove aplikacije, vključujoč naprave za shranjevanje in pretvorbo energije (ESC). V zvezi s tem je namen tega predmeta kontekstualizirati nedavni napredek ogljikovih materialov z zagotavljanjem širšega pogleda na njihove lastnosti, na sintezne poti, njihove lastnosti in funkcionalizacije. Poleg opisa različnih vrst materialov iz ogljikovih alotropov, bo zajeta tudi njihova uporaba in vloga v ESC.

Content (Syllabus outline):

Carbon based materials are indispensable in modern technologies. Furthermore, recent development of carbon nanomaterials has resulted in intensive scientific activity with a goal to develop new class of materials for new applications including energy storage and conversion (ESC). In this respect this course aims to contextualize the recent advances in carbon materials by providing a broader view of their properties, how they are synthesized, how they are characterized, and how they are functionalized. Besides describing different types and uses of carbon allotrope materials, their application and role in ESC will be also be covered.

Temeljni literatura in viri / Readings:

1.) Wen Lu, Jong-Beom Baek, Liming Dai, *Carbon Nanomaterials for Advanced Energy Systems,* John Wiley & Sons, Inc., **2015**, Print ISBN:9781118580783 (80%)
2.) Brownson, Dale A. C., Banks, Craig E., *The Handbook of Graphene Electrochemistry*, Springer-Verlag London, **2014**, Hardcover ISBN: 978-1-4471-6427-2 (10%)
3.) Recent articles from the literature (10%).

Cilji in kompetence:	**Objectives and competences:**
Cilj predmeta študentje bodo znali: Določiti, kaj so ogljikovi materiali, in prepoznati različne alotropne modifikacije ter njihovo uporabo. Razumeli bodo sintezo, funkcionalizacijo, karakterizacijo in načine uporabe za različne ogljikove alotrope. Razumeli bodo uporabo alotropov ogljika v napravah ESC. Znali bodo ugotoviti in razložiti, zakaj imajo nanoogljiki drugačne lastnosti kot njihovi volumenski materiali. *Kompetence*: znanje, kako oblikovati in napisati manjši predlog raziskav v zvezi z uporabo ogljikovih alotropov v napravah ESC. Pridobljeno znanje je neposredno prenosljivo na druga znanstvena področja, kot so kemija, kemijsko inženirstvo in elektrotehnika.	*Objectives* students will be able to: Define what carbon materials are, identify different allotropes and their applications. Understand synthesis, functionalization, characterization and application routes for various carbon allotropes. Understand application of carbon allotropes in ESC devices. Identify and explain why nanocarbons have different properties from their bulk counterparts. *Competences*: ability to design and write a small research proposal related to application of carbon allotropes in ESC devices. Acquired knowledge is directly transferable to other fields of science such as chemistry, chemical engineering, and electrical engineering.
Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanje in razumevanje: Študenti spoznajo lastnosti ogljikovih alotropov, sintezo, funkcionalizacijo in aplikacije, povezane z materiali za shranjevanje in pretvorbo energije. Pridobljeno znanje znajo uporabiti za reševanje problemov za naprave za shranjevanje in pretvorbo energije nove generacije v akademskih krogih in evropski industriji. Znajo uporabiti znanje za reševanje trenutnih problemov alternativnih tehnologij prihodnosti.	Knowledge and understanding: Students learn about carbon allotropes properties, synthesis, functionalization and applications related to energy storage and conversion materials. They can apply the acquired knowledge to problem solving for the next generation energy storage and conversion devices in academia and European industry. They can apply their knowledge to solving current problems of important alternative technologies of the future.

Metode poučevanja in učenja:	**Learning and teaching methods:**
Predavanja, seminarji s preučevanjem člankov in diskusijo, laboratorijsko delo.	Lectures, seminars with literature study and discussions, labwork.

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

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.

(2) Genorio, B.; Lu, W.; Dimiev, A. M.; Zhu, Y.; Raji, A.-R. O.; Novosel, B.; Alemany, L. B.; Tour, J. M. In Situ Intercalation Replacement and Selective Functionalization of Graphene Nanoribbon Stacks. *ACS Nano* **2012**, *6* (5), 4231–4240. https://doi.org/10.1021/nn300757t.

(3) Vizintin, A.; Lozinšek, M.; Chellappan, R. K.; Foix, D.; Krajnc, A.; Mali, G.; Drazic, G.; Genorio, B.; Dedryvère, R.; Dominko, R. Fluorinated Reduced Graphene Oxide as an Interlayer in Li–S Batteries. *Chem. Mater.* **2015**, *27* (20), 7070–7081. https://doi.org/10.1021/acs.chemmater.5b02906.

(4) Strmcnik, D.; Lopes, P. P.; Genorio, B.; Stamenkovic, V. R.; Markovic, N. M. Design Principles for Hydrogen Evolution Reaction Catalyst Materials. *Nano Energy* **2016**, *29*, 29–36. https://doi.org/10.1016/j.nanoen.2016.04.017.

(5) Staszak-Jirkovský, J.; Malliakas, C. D. D.; Lopes, P. P. P.; Danilovic, N.; Kota, S. S. S.;

Chang, K.-C.; Genorio, B.; Strmcnik, D.; Stamenkovic, V. R. R.; Kanatzidis, M. G.; et al. Design of Active and Stable Co-Mo-Sx Chalcogels as PH-Universal Catalysts for the Hydrogen Evolution Reaction. *Nat. Mater.* **2016**, *15* (November), 197–203. https://doi.org/10.1038/nmat4481.

(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.* **2018**, *8* (1), 5819. https://doi.org/10.1038/s41598-018-23991-2.

UČNI NAČRT

UČNI NAČRT PREDMETA / COURSE SYLLABUS	
Predmet:	Analizna kemija
Course title:	Analytical chemistry

Študijski program in stopnja Study programme and level	Študijska smer Study field	Letnik Academic year	Semester Semester
MAG Kemija, 2. stopnja	Materiali za shranjevanje in pretvorbo energije	2.	3.
USP Chemistry, 2nd Cycle	Materials for Energy Storage and Conversion	2st	3rd

Vrsta predmeta / Course type	Obvezni / Mandatory
Univerzitetna koda predmeta / University course code:	

Predavanja Lectures	Seminar Seminar	Vaje Tutorial	Klinične vaje work	Druge oblike študija	Samost. delo Individ. work	ECTS
30	15	30	/	/	75	6

Nosilec predmeta / Lecturer:	izr. prof. dr. Mitja Kolar/ dr. Mitja Kolar, Associate Professor

Jeziki / Languages:	**Predavanja / Lectures:**	**angleški/ English**
	Vaje / Tutorial:	**angleški/ English**

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

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.

Opravljanje študijskih obveznosti: predpogoj za pristop h kolokviju iz laboratorijskih vaj je uspešno zaključen praktični del vaj; opravljen kolokvij iz vaj je predpogoj za pristop k pisnemu izpitu.

Prerequisites:

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.

Assessment prerequisites: successfully accomplished lab work is a precondition for attending the written assessment; successfully accomplished laboratory tutorial is a precondition to attend the written exam.

Vsebina:

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, kompleksometrične, obarjalne in redoks določitve (potek titracijskih krivulj, načini ugotavljanja končne točke, izbira indikatorjev, izbrani primeri določitev, avtomatizacija).

Content (Syllabus outline):

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 (titration curve, types of indicators, analytical applications, automatization.)

Introduction to electrochemistry and electrochemical methods: Potentiometry (method characteristics,

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). 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 spektrometrija (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 študenti usposobijo za praktično izvedbo klasičnih in instrumentalnih analiznih metod.	measuring system, types of electrodes, approaches for determining concentration, potentiometric titrations); Voltammetry (method characteristics, measuring system, voltammogram-interpretation, novel electrode materials, techniques). Conductometry, coulometry, amperometry and electrogravimetry (method characteristics and analytical applications). 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.

Temeljni 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:

Pri predmetu študenti osvojijo temelje analizne kemije, spoznajo različne analizne pristope in uporabo klasičnih ter instrumentalnih analiznih metod za reševanje realnih primerov.

Objectives and competences:

Students learn the fundamentals of analytical chemistry, analytical approach and application of classical and instrumental analytical methods for real sample analysis.

Predvideni študijski rezultati:

Znanje in razumevanje

Študenti razumejo temelje analizne kemije, osvojijo analizni pristop ter razumejo in znajo uporabljati klasične in instrumentalne analizne metode, s poudarkom na pravilni interpretaciji analiznih rezultatov.

Uporaba

Študenti znajo podajati in vrednotiti analizne rezultate ter razlikujejo med različnimi principi določitev. Študenti obvladajo računske vidike obravnavanih analiznih metod.

Refleksija

Študenti imajo kritičen odnos do rezultatov analiz in predstavljenih analiznih metod.

Prenosljive spretnosti

Laboratorijske spretnosti, pravilno podajanje in statistično vrednotenje analiznih rezultatov.

Intended learning outcomes:

Knowledge and Comprehension

Students understand 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

Students develop the ability of presenting and evaluating analytical results. Students master calculation procedures related to the presented analytical methods.

Analysis

Students develop 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, laboratory tutorial.

Načini ocenjevanja:	Delež (v %) / Weight (in %)	**Assessment:**
Laboratorijske vaje:		Laboratory tutorial:
kakovost analiznih rezultatov;	**25%**	quality of analytical results;
kolokvij.	**25%**	written assessment.
Pisni izpit.	**50%**	Written exam.

Reference nosilca / Lecturer's references:

1.) IVANOVIĆ, Milena, ISLAMČEVIĆ RAZBORŠEK, Maša, KOLAR, Mitja. Simultaneous GC-MS determination of free and bound phenolic acids in Slovenian red wines and chemometric characterization. Acta chimica slovenica, ISSN 1318-0207. [Tiskana izd.], 2016, vol. 63, no. 3, str. 661-669.

2.) HUŠ, Sebastjan, KOLAR, Mitja, KRAJNC, Peter. Separation of heavy metals from water by functionalized glycidylmethacrylate poly (high internal phase emulsions). Journal of chromatography. A, ISSN 0021-9673, 2016, vol. 1437, str. 168-175.

3.) ZIDARIČ, Tanja, JOVANOVSKI, Vasko, MENART, Eva, ZORKO, Milena, KOLAR, Mitja, VEBER, Marjan, HOČEVAR, Samo B. Multi-pulse galvanostatic preparation of nanostructured bismuth film electrode for trace metal detection. Sensors and actuators. B, Chemical, ISSN 0925-4005. [Print ed.], Jun. 2017, vol. 245, str. 720-725.

UČNI NAČRT PREDMETA / COURSE SYLLABUS	
Predmet:	Magistrsko delo
Course Title:	Master Thesis

Študijski program in stopnja Study Programme and Level	Študijska smer Study Field	Letnik Academic Year	Semester Semester
MAG Kemija, 2. stopnja	**Materiali za shranjevanje in pretvorbo energije**	**2.**	**4.**
USP Chemistry, 2nd Cycle	**Materials for Energy Storage and Conversion**	**2nd**	**4th**

Vrsta predmeta / Course Type: obvezni / Mandatory

Univerzitetna koda predmeta / University Course Code:

Predavanja Lectures	Seminar Seminar	Vaje Tutorial	Klinične vaje Work	Druge oblike študija	Samost. delo Individual Work	ECTS
/	/	/	/	450	450	30

Nosilec predmeta / Lecturer: /

Jeziki / Languages:

Predavanja / Lectures:	**angleški /English**
Vaje / Tutorial:	**angleški / English**

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

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.

Prerequisites:

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:

Magistrsko delo se opravlja na področju kemije, smer MESC+. Vsebina in naslov se določata v soglasju z izbranim mentorjem.

Content (Syllabus outline):

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:**
<u>Znanje in razumevanje</u> 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	<u>Knowledge and Comprehension</u> 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.
<u>Uporaba</u> Znanje in pridobljene veščine bo magistrant lahko uporabil pri opravljanju poklica.	<u>Application</u> Acquired skills are necessary for professional work.
<u>Refleksija</u> Povezovanje vseh pridobljenih teoretičnih znanj z reševanjem problemov na področju kemije ter kritični pogled na uporabnost teh znanj.	<u>Analysis</u> Integration of knowledge from different topics from chemistry and supporting sciences; Development of a critical view on the knowledge applicability.

Prenosljive spretnosti	Skill-transference Ability
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.	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 (v %) / Weight (in %)	**Assessment:**
Komisija za oceno in zagovor magistrskega dela oceni magistrsko delo in zagovor.	**100%**	Master thesis and its presentation are graded by the thesis commitee.

Reference nosilca / Lecturer's references:

/