UČNI NAČRT PREDMETA / COURSE SYLLABUS	
Predmet:	IZBRANA POGLAVJA IZ MATERIALOV ZA ENERGETIKO
Course Title:	SELECTED TOPICS IN MATERIALS FOR NEW ENERGY SOURCES

Študijski program in stopnja Study Programme and Level	Študijska smer Study Field	Letnik Academic Year	Semester Semester
DR Kemijske znanosti, 3. stopnja	**/**	**1.**	**1. in 2.**
Doctoral programme in Chemical Sciences, 3rd Cycle	**/**	**1st**	**1st and 2nd**

Vrsta predmeta / Course Type: izbirni/Elective

Univerzitetna koda predmeta / University Course Code: KZ322A

Predavanja Lectures	Seminar Seminar	Vaje Tutorial	Klinične vaje Work	Druge oblike študija	Samost. delo Individual Work	ECTS
15	**15**	**/**	**/**	**90**	**30**	**5**

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

Jeziki / Languages:

Predavanja / Lectures:	**slovenski / Slovenian**
Vaje / Tutorial:	**slovenski / Slovenian**

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

Študent oz. kandidat mora imeti predmet opredeljen kot študijsko obveznost.

Prerequisites:

The course has to be assigned to the student.

Vsebina:

Študent s soglasjem mentorja med spodaj navedenimi temami v izbere tiste, ki so najtesneje povezane z njegovim raziskovalnim delom. Nosilec predmeta in vodja študija poskrbita, da obseg študentovega dela ustreza 5 KT. Če je nosilcev več, izvajanje koordinira nosilec.

Materiali za sodobne energijske pretvornike

Vodikova tehnologija:

- Tehnologije za pridobivanje vodika (predelava ogljikovodikov – parni reforming, WGSR, elektrolizni postopki, termokemijska

Content (Syllabus outline):

Together with mentor the student chooses the course contents with the total of 5 credits among the topics listed below. If there is more than one lecturer on the course, the course coordinator takes care of the implementation of the program.

Materials for new energy converters

Hydrogen Technology:

- Technologies for hydrogen production (processing of hydrocarbons – steam reforming, water gas shift reaction, electrolytic processes, thermo-chemical dissociation of water, conversion of biomass to hydrogen).

disociacija vode, predelava biomase do vodika) - Shranjevanje in distribucija vodika (tlačni sistemi, kriogeni sistemi, shranjevanje vodika v obliki hidridov, CNT idr.; distribucija vodika, varnost vodikovih tehnologij), *Gorivne celice:* - Vrste gorivnih celic in principi njihovega delovanja (specifika glede uporabljenega goriva in zahtev po njegovi čistosti, temperature delovanja, uporabljenih materialov, prenosa naboja v celici) - Materiali za elektrolit, elektrodi in vmesnik (zahtevane karakteristike za materiale v gorivnih celicah, elektrokatalizatorji - Delovanje gorivnih celic njihov izkoristek in vplivi na okolje (aktivacijske, omske, koncentracijske in druge polarizacijske izgube, sistemi gorivnih celic in potrebna infrastruktura, izkoristki gorivnih celic, kogeneracija toplote v gorivnih celicah, vplivi na okolje pri neposredni pretvorbi kemijske energije v električno) *Li ionski in drugi akumulatorji:* - Princip delovanja izbranih klasičnih in sodobnih insercijskih baterij in akumulatorjev (shranjevanje naboja na površini oziroma v notranjosti strukture, homogena vgradnja ter vgradnja s faznimi prehodi, vpliv na termodinamske in kinetične lastnosti) - Materiali za anodo, elektrolit, in katodo (grafitni materiali, litijeve zlitine, oksidni materiali, žveplova katoda, katoda z zračno depolarizacijo, tekoči elektroliti, polimerni elektroliti, elektroliti na osnovi ionskih tekočin) - Karakteristike najperspektivnejših akumulatorjev (litijevi insercijski, litij zrak, polimerni, litij žveplo) *Superkondenzatorji:* - Princip delovanja superkondenzatorja (fazna meja trdno-tekoče, električni dvosloj, termodinamika in kinetika tipičnega superkonden-zatorja, vpliv poroznosti, vpliv površinskih skupin, razlika med kemijskim in elektrokemijskim sharnjevanjem na površini)	- Storage and distribution of hydrogen (pressurized systems, cryogenic systems, storage of hydrogen in hydride form, CNT etc.: distribution of hydrogen, safety of hydrogen technologies). *Fuel cells:* - Types of fuel cells and principles of their operation (fuel sources and its purity, temperature of operation of a FC, materials used in the construction of a cell, charge transfer). - Materials for electrolyte, electrodes and interconnect (prerequisites for characteristics of the materials in fuel cells, electrocatalysts). - Operation of fuel cells, yield of energy conversion and environmental impact (activation, ohmic, concentration and other polarization losses fuel cell systems and their infrastructure, yield of fuel cells, cogeneration of heat in fuel cells, environmental impact in direct conversion of the chemical energy into electrical energy). *Li ion and other batteries:* - Principles of operation of classical and new insertial batteries and accumulators (charge storage on surfaces/interfaces and in bulk, homogeneous insertion and insertion via phase transformation, influence of kinetic and thermodynamic properties). - Materials for anodes, electrolytes and cathodes (graphite-based materials, lithium alloys, oxides and sulphides, sulphur cathode, air electrodes, liquid polymeric and mixed electrolytes, electrolytes based on ionic liquids). - Chaeracteristics of advanced accumulators (lithium insertion batteries, Li air battery, polymer accumulators, lithium-sulphur accumulator). *Supercapacitors:* - Principle of operation of supercapacitor (solid-liquid interface, electrical double layer, thermodynamics and kinetics of typical supercapacitor, influence of porosity, surface groups, difference between electrostatic and chemical charge storage on surfaces).

- Materiali za anodo, elektrolit, in katodo (grafitni materiali, tekoči elektroliti, polimerni elektroliti) - Karakterizacija, lastnosti in uporaba izbranih superkondenzatorjev Materiali in varovanje okolja (materiali za zmanjšanje emisij v okolje, odstranjevanje HOS – hlapnih organskih spojin (VOC – volatile organic compounds), razvoj katalitskih materialov in sistemov, življenska doba in vplivi različnih skupin materialov na okolje). Seminar iz izbranega področja materialov za energetiko, ki temelji na pregledu strokovne in znanstvene literature. Izdelava predloga raziskovalnega projekta za enžinirstvo specifičnega materiala za energetiko.	- Materials for anode, electrolyte, and cathode (graphitic materials, aqueous and nonaqueous electrolytes). - Characterization, properties and application of selected supercapacitors Materials for environment protection (materials for lowering of emissions into environment, removal of VOC – volatile organic compounds), development of catalytic materials and systems, lifetime cycles and impact of different groups of materials on the environment). A seminar from a selected topic of materials for new energy sources, which is based on scientific and professional literature review. Elaboration of a project proposal for engineering of a specific material for new energy sources

Temeljna literatura in viri / Readings:

Predlagana literatura za pregled vsebinskih področij / Recommended readings for topics review:

- Fuel Cell Handbook (7th Edition), EG&G Technical Services, INC, Morgantown, West Virginia, 2004
- High Temperature Fuel Cells: Fundamentals, Design and Applications, Ed. S.C. Singhal, K. Kendall, Elsevier, Kindlington, UK, 2004
- Lithium-Ion Batteries, Ed. M. Yoshio, R. Brodd, A. Kozawa, Springer, NY, USA, 2009
- Lithium-Ion Batteries: Advanced Materials and Technologies, X. Yuan, H. Liu, J. Zhang, CRC Press, USA, 2011

Literatura za seminar / Seminar readings:

Najnovejša znanstvena literatura (monografije, članki) z izbranega študijskega področja, ki se spreminja v skladu z razvojem stroke. Študenti literaturo zbirajo samostojno med študijskim procesom s pomočjo usmerjanja učitelja. / The newest literature (monographies, papers) from the selected field. Students will perform a literature research being supported and guided by the lecturer.

Cilji in kompetence:	**Objectives and Competences:**
Seznanjanje z materiali za sodobne aplikacije v energetiki in okoljevarstvu. Podiplomski študenti bodo preučili dostopno strokovno in znanstveno literaturo iz izbranega področja in jo kritično ovrednotili. V okviru tega predmeta študent pridobi specialistična znanja z ožjega področja. Ta znanja zadostujejo za samostojno vodenje znanstvene raziskave na izbranem raziskovalnem področju.	Acquiring specialized knowledge in specific fields of materials for new energy sources. Studying scientific and professional literature in a specific field, critical evaluation of literature. These competences enable students to conduct research in a particular research field, to suggest research methods and to state its goals.

Predvideni študijski rezultati:	**Intended Learning Outcomes:**
Znanje in razumevanje Študent zna samostojno preučevati znanstveno literaturo s področja materialov za energetiko. Pridobi poglobljena znanja o izbrani tematiki.	Knowledge and Comprehension Student comprehends scientific literature in the field of materials for new energy sources. Gains specific and detailed knowledge on selected topics.
Uporaba Pridobljena znanja in uporabljene pristope je sposoben uporabiti pri samostojnem razvojnem in raziskovalnem delu na področju enžinerstva materialov za energetiko.	Application Acquired knowledge and used approaches are necessary for independent research and development in the field of materials for new energy sources.
Refleksija Študent je sposoben samostojno definirati problem, načrtovati vsebino raziskovalnega dela, predvideti metode dela ter postaviti raziskovalne cilje.	Analysis Student is able to define problems, propose the content of a research project, suggest research methods and state its goals.
Prenosljive spretnosti Študent je sposoben kritično analizirati in povezovati literaturne podatke, sintetizirati različna znanja, zagovarjati rezultate ter sodelovati v diskusiji.	Skill-transference Ability Ability to critically interpret and interconnect literature data, to synthesize knowledge, to defend project results and to discuss them.

Metode poučevanja in učenja:	**Learning and Teaching Methods:**
Metode so prilagojene študentu oziroma skupini: predavanja, študij ustrezne strokovne literature, laboratorijsko delo na izbranem področju, seminar, raziskovalni projekt in razprave v ožji skupini.	Methods are adapted to a student or group of students: lectures, study of the literature, laboratory work in the selected field, seminars, elaboration of a project and discussions in a group.

Načini ocenjevanja:	Delež (v %) / Weight (in %)	**Assessment:**
Predloženo poročilo o projektem delu ali seminar v pisni obliki	50 %	Written project report or seminar work
Ustni zagovor projektne naloge	50 %	Oral project defence

Reference nosilca / Lecturer's references:

1. Connell, J. G.; Genorio, B.; Lopes, P. P.; Strmcnik, D.; Stamenkovic, V. R.; Markovic, N. M. Tuning the Reversibility of Mg Anodes via Controlled Surface Passivation by H 2 O/Cl - in Organic Electrolytes. Chem. Mater. 2016, 28, 8268–8277. https://doi.org/10.1021/acs.chemmater.6b03227.
2. 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.
3. Genorio, B.; Staszak-Jirkovský, J.; Assary, R. S.; Connell, J. G.; Strmcnik, D.; Diesendruck, C. E.; Lopes, P. P.; Stamenkovic, V. R.; Moore, J. S.; Curtiss, L. A.; et al. Superoxide (Electro)Chemistry on Well-Defined Surfaces in Organic Environments. J. Phys. Chem. C 2016, 120, 15909–15914. https://doi.org/10.1021/acs.jpcc.5b12230.

4. 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.
5. Vizintin, A.; Genorio, B.; Dominko, R. CHAPTER 8: Application of Graphene Derivatives in Lithium-Sulfur Batteries; 2018; Vol. 2018–Janua. https://doi.org/10.1039/9781788012829-00222.
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.