UČNI NAČRT PREDMETA / COURSE SYLLABUS	
Predmet:	Okolju prijazni piezoelektrični keramični materiali
Course title:	Environmentally-Friendly Piezoelectric Ceramic Materials

Študijski program in stopnja Study programme and level	Študijska smer Study field	Letnik Academic year	Semester Semester
Ekotehnologije, 3. stopnja	/	1	1
Ecotechnologies, 3rd cycle	/	1	1

Vrsta predmeta / Course type Izbirni/Elective

Univerzitetna koda predmeta / University course code: EKO3-745

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

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

Nosilec predmeta / Lecturer: Doc. dr. Andreja Benčan Golob

Jeziki / Languages:	**Predavanja / Lectures:**	slovenščina, angleščina Slovenian, English
	Vaje / Tutorial:	

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	**Prerequisits:**
Zaključen študij druge stopnje ustrezne (naravoslovne ali tehniške) smeri ali zaključen študij drugih smeri z dokazanim znanjem osnov področja predmeta (pisna dokazila, pogovor).	Completed second level studies in natural sciences or engineering or completed second level studies in other fields with proven knowledge of fundamentals in the field of this course (certificates, interview).

Vsebina:	**Content (Syllabus outline):**
• Smernice razvoja okolju prijazne piezoelektrične keramike. • Sintezne metode okolju prijazne piezoelektrične keramike s poudarkom na sintezi materialov na osnovi alkalijskih niobatov in bizmutovega ferita (volumenska keramika, debele in tanke plasti, monokristali). Kritični parametri sinteze, ki vplivajo na funkcionalne lastnosti študiranih materialov. • Novejše metode za strukturno, mikrostrukturno, električno, elektro-mehansko karakterizacijo okolju prijaznih piezoelektričnih materialov (od lokalnih do makroskopskih odzivov).	• Development trends in environmentally -friendly piezoelectric materials. • Synthesis methods of environmentally-friendly piezoelectric materials based on alkaline niobates and bismuth ferrite (bulk, thick films, thin films and single crystals). Critical synthesis parameters which influence the functional properties of the studied materials. • Advanced methods for structural, microstructural, electrical, electro-mechanical characterization of environmentally -friendly piezoelectric materials (from local to macroscopic responses).

• Individualno poglobljena analiza izbranega realnega primera iz študentove disertacije: izbor primerne metode sinteze materiala in ustreznih metod karakterizacije.	• Individual analysis of a case study related to the topic of the student's PhD research: selection of a suitable synthesis method of the studied material, and characterization methods.

Temeljni literatura in viri / Readings:

Metal Oxides Series, Magnetic, Ferroelectric, and Multiferroic Metal Oxides, Edited by B. Stojanovic, Series editor G. Korotcenkov, Elsevier, 2018.

K. Uchino, Ferrolectric Devices 2nd edition, Taylor and Francis Group, 2009.

Izbrani članki predvsem v revijah Nature Materials, Advanced Functional Materials, Chemistry of Materials, Journal of the American Ceramic Society, Journal of European Ceramic Society ter pregledni članki. / Targeted selection of papers from Nature Materials, Advanced Functional Materials, Chemistry of Materials, Journal of the American Ceramic Society, Journal of the European Ceramic Society and review papers.

Cilji in kompetence:	**Objectives and competences:**
Cilj predmeta je seznaniti študente z osnovami sinteznih metod ter z metodami karakterizacije okolju prijaznih piezoelektričnih materialov. Študent bo znal oceniti pomembne kemijske in fizikalne lastnosti okolju prijaznih piezoelektričnih materialov in njihove omejitve. Kompetence: • obvladovanje izbranih raziskovalnih metod, postopkov, procesov, • sposobnost samostojne kritične presoje, • sposobnost uporabe znanj v praksi.	The objective of the course is to introduce to students principles of synthesis and characterization methods for environmentally friendly piezoelectric materials. The student will be able to evaluate chemical and physical properties of environmentally-friendly piezoelectric materials and their limitations. Competences: • mastering of selected research methods, procedures and processes • development of critical thinking • ability to use knowledge in practice

Predvideni študijski rezultati:	**Intended learning outcomes:**
Študent bo na osnovi pridobljenega znanja: • obvladal kriterije primerjave različnih skupin okolju prijaznih piezoelektričnih materialov • izbral primerno metodo sinteze okolju prijaznih piezoelektričnih materialov • napovedal eksperimentalne omejitve posameznih metod okolju prijaznih piezoelektričnih materialov • izbral primerne metode karakterizacije okolju prijaznih piezoelektričnih materialov • znal interpretirati rezultate analiz • znal povezovati znanja o okolju prijaznih piezoelektričnih materialih in sodobnih tehnologij za reševanje konkretnega primera v okviru doktorskega študija.	The student will: • master the criteria of different groups of environmentally friendly-piezoelectric materials • select a suitable method of synthesis of environmentally-friendly piezoelectric materials • forecast experimental limitations • select suitable methods of characterization • interpret the results of analysis • be able to correlate knowledge in the field of synthesis of environmentally-friendly piezoelectric materials and advanced technologies to solve a case-study related to the PhD research.

Metode poučevanja in učenja:	**Learning and teaching methods:**
Interaktivna predavanja. Individualno voden študij, ki vključuje reševanje realnega primera in predstavitev rezultatov v obliki seminarske naloge.	Interactive lectures. Individually guided study, which includes a case-study and presentation of results as a seminar.

Načini ocenjevanja:	Delež (v %) / Weight (in %)	**Assessment:**
Seminarska naloga.	50 %	Seminar.
Zagovor reševanja izbranega primera.	50 %	Defense of the case-study .

Reference nosilca / Lecturer's references:

1.ROJAC, Tadej, BENČAN, Andreja, DRAŽIĆ, Goran, SAKAMOTO, Naonori, URŠIČ, Hana, JANČAR, Boštjan, TAVČAR, Gašper, MAKAROVIČ, Maja, WALKER, Julian, MALIČ, Barbara, DAMJANOVIĆ, Dragan. Domain-wall conduction in ferroelectric $BiFeO_3$ controlled by accumulation of charged defects. Nature materials, ISSN 1476-1122, 2017, vol. 16, no. 3, str. 322-327, doi: 10.1038/nmat4799. [COBISS.SI-ID 29936679]

2.HREŠČAK, Jitka, DRAŽIĆ, Goran, DELUCA, Marco, ARČON, Iztok, KODRE, Alojz, DAPIAGGI, Monica, ROJAC, Tadej, MALIČ, Barbara, BENČAN, Andreja. Donor doping of $K_{0.5}Na_{0.5}NbO_3$ ceramics with strontium and its implications to grain size, phase composition and crystal structure. Journal of the European ceramic society, ISSN 0955-2219. [Print ed.], 2017, vol. 37, iss. 5, str. 2073-2082, ilustr., doi: 10.1016/j.jeurceramsoc.2016.12.053. [COBISS.SI-ID 4638715],

3. HREŠČAK, Jitka, MALIČ, Barbara, CILENŠEK, Jena, BENČAN, Andreja. Solid-state synthesis of undoped and Sr-doped $K_{0.5}Na_{0.5}NbO_3$, Study by thermal analysis and in situ high-temperature X-ray diffraction. Journal of thermal analysis and calorimetry, ISSN 1388-6150. [Print ed.], 2017, vol. 127, no. 1, str. 129-136, doi: 10.1007/s10973-016-5615-3. [COBISS.SI-ID 29608999],

4. KHOMYAKOVA, Evgeniya, ŠADL, Matej, URŠIČ, Hana, DANIELS, John, MALIČ, Barbara, BENČAN, Andreja, DAMJANOVIĆ, Dragan, ROJAC, Tadej. Self-poling of $BiFeO_3$ thick films. ACS applied materials & interfaces, ISSN 1944-8244. [Print ed.], 2016, vol. 8, no. 30, str. 19626-19634, doi: 10.1021/acsami.6b05885. [COBISS.SI-ID 29643559]

5. ROJAC, Tadej, URŠIČ, Hana, BENČAN, Andreja, MALIČ, Barbara, DAMJANOVIĆ, Dragan. Mobile domain walls as a bridge between nanoscale conductivity and macroscopic electromechanical response. Advanced functional materials, ISSN 1616-301X, 2015, vol. 25, no. 14, str. 2099-2108, doi: 10.1002/adfm.201402963. [COBISS.SI-ID 28359975]