UČNI NAČRT PREDMETA / COURSE SYLLABUS	
Predmet:	Procesiranje in nanomagnetizem kompleksnih intermetalnih zlitin
Course title:	Processing and Nanomagnetism of Complex Intermetallic Alloys

Študijski program in stopnja Study programme and level	Študijska smer Study field	Letnik Academic year	Semester Semester
Nanoznanosti in nanotehnologije, 3. stopnja	/	1	1
Nanosciences and Nanotechnologies, 3rd cycle	/	1	1

Vrsta predmeta / Course type Izbirni / Elective

Univerzitetna koda predmeta / University course code: NANO3-896

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

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

Nosilec predmeta / Lecturer: Prof. dr. Spomenka Kobe
Doc. dr. Kristina Žužek-Rožman
Prof. dr. Jean-Marie Dubois

Jeziki / Languages:		
	Predavanja / Lectures:	Slovenščina, angleščina / Slovene/ English
	Vaje / Tutorial:	

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	**Prerequisits:**
Osnovno znanje na področju kemije, metalurgije, fizike in vede o materialih.	Basic knowledge in the fields of Chemistry, Metallurgy, Physics and Material Sciences.

Vsebina:	**Content (Syllabus outline):**
Procesiranje magnetnih in drugih intermetalnih kompleksnih zlitin je izjemnega pomena za njihove končne magnetne in druge fizikalne lastnosti. Nanomagnetizem je že zdaj izredno pomemben pri izboljšavi lastnosti magnetnih materialov za uporabo v motorski aplikaciji za električna vozila in vetrne elektrarne. Izjemno pomemben je tudi pri shranjevanju spomina, za senzorsko uporabo in pri izdelavi mehanizmov, strmo pa narašča tudi uporaba v t.i. življenjski znanosti (life-science) in medicini. Izmenjalne interakcije znotraj strukture in interfaznih mej osnovnih magnetnih in drugih kompleksnih intermetalnih zlitin v »bulk« obliki ter nanostruktur, izmenjalna anizotropija, gigantska	Processing of magnetic and other complex intermetallic alloys is exceptionally important in tailoring their final physical properties. Nanomagnetism has already a special role in highly sophisticated methods for improving the magnetic properties of materials for motor application in electric vehicles and wind turbines for clean environment. Nanomagnetism has a special role to play as magnetic properties depend uniquely on both dimensionality and length scales. Nanomagnetism is already central to data storage, sensor and device technologies, but is increasingly being used in the life sciences and medicine. The interlayer exchange interactions within magnetic multilayer structures at

magnetostrikcija (GMR) in tunelska magneto-upornost (TMR), magnetokalorični efekt, optične lastnosti ter transportne lastnosti elektronov v materialu so lastnosti izrednega tehnološkega pomena. Študij bo delno usmerjen na izdelavo osnovnih materialov s posebnimi lastnostmi ter nano strukturnih materialov, katerih lastnosti se zaradi drugačnih dimenzij, predvsem pa zaradi bistveno večje površine, zelo spremenijo. Poudarek bo na študiju vpliva priprave na končne magnetne in druge fizikalne lastnosti z uporabo različnih fizikalnih metod karakterizacije ter visoko ločljivih analitskih tehnik elektronske mikroskopije. Poudarek pri kemijskem načinu priprave tankih filmov in nano objektov (žice, sfere, cevke) s posebnimi magnetnimi lastnostmi bo na elektrolitski in elektroforetski metodi (ELD, EPD).	interfaces, the static, dynamic and thermal properties of magnetic multilayer and nanostructures, exchange anisotropy, giant magnetoresistance (GMR) and tunneling magnetoresistance (TMR), magnetocalloric effect, optical properties, transport properties of electrons are issues of high technological importance. The emphasis will be on the influence of the processing parameters on tailoring the final magnetic and other physical properties. Fabrication of nanodevices and nanostructures of various materials properties will be studied by a variety of physical methods and high resolution electron microscopy analytical techniques. The study of chemical methods for preparation of magnetic thin films and nano objects (wires, spheres, tubes) will be mainly electrodeposition and electrophoretic deposition (ELD, EPD).

Temeljna literatura in viri / Readings:

Principles of Nanomagnetism, Guimaraes A.P., Springer, 2009
Magnetism and Magnetic Materials, J.M.D. Coey, April 2010, ISBN: 9780521816144
Concerted European Action on Magnets, I.V. Mitchell, J.M. Coey et. al., 2012 ISBN-13: 978-9401070034
The applied physics of quasicrystals; J.M. DUBOIS, Scripta Physica, T49 (1993) 17-23.
Useful Quasicrystals; J.M. DUBOIS, *World Scientific, Singapour (2005), 470 pages*.
Nanoscale Magnetic Materials and Applications, Ping Liu J. Et al., Springer, 2009

Selected publications

Application of quasicrystalline alloys to surface coating of soft metals; J.M. DUBOIS, S.S. KANG, Y. MASSIANI, J. Non Cryst. Solids, 153-154 (1993) 443-445.
Properties- and applications of complex metallic alloys, J.M. DUBOIS, *Chem. Soc. Rev., 41 (2012) 6760-6777.*
Quasicrystal-polymer composites for selective laser sintering technology; S. KENZARI, D. BONINA, J.M. DUBOIS, V. FOURNEE, *Materials and Design, 35 (2012) 691-95.*
Random-anisotropy ferromagnetic state in the $Cu_5Gd_{0.54}Ca_{0.42}$ intermetallic compound, M. Krnel, J.-M. Dubois, J. Dolinšek et al., *Physical review. B, Condensed matter and materials physics*, ISSN 1098-0121, 2016, vol. 93, no. 9, pp. 094202-1-094202-14
Additive manufacturing of lightweight, fully Al-based components using quasicrystals; S. Kenzari, D. Bonina, J.-M. Dubois, V Fourneé, *Journal of materials processing technology*, ISSN 0924-0136, 2014, vol. 214, no. 12, str. 3108-3111
Properties of SPS-processed permanent magnets prepared from gas-atomized Nd-Fe-B powders T. Tomše, J. Jaćimović, J.-M. Dubois, S. Kobe et al., *Journal of alloys and compounds*, ISSN 0925-8388, [in press] 2018, 20 str., doi: 10.1016/j.jallcom.2018.01.411
Hybrid FePt/SiO2/Au nanoparticles as theranostic tool: in vitro photo-thermal treatment and MRI imaging, N. Kostevšek, et. al., S. Kobe, K. Žužek Rožman, *Nanoscale*, ISSN 2040-3364, [in press] 2017, 16 str., doi: 10.1039/C7NR07810B
High-coercivity Nd-Fe-B magnets obtained with the electrophoretic deposition of submicron TbF_3 followed by the grain-boundary diffusion process, M. Soderžnik, M. Korent, K. Žagar, et.al., S. Kobe, *Acta*

materialia, ISSN 1359-6454, 2016, vol. 115, str. 278-284, doi: 10.1016/j.actamat.2016.06.003
Magnetic and microstructural investigation of high-coercivity net-shape Nd-Fe-B-type magnets produced from spark-plasma-sintered melt-spun ribbons blended with DyF_3, K. Žagar, A. Kocjan, S. Kobe, *Journal of Magnetism and Magnetic Materials*, ISSN 0304-8853, 2016, vol. 403, str. 90-96, doi: 10.1016/j.jmmm.2015.11.082

Cilji in kompetence:

Študentje spoznajo kemijske (ELD, EPD), metalurške in fizikalne metode (ultra hitro kaljenje litin, visokoenergijsko mletje, pulzna laserska depozicija) procesiranja intermetalnih magnetnih in drugih kompleksnih zlitin kot osnovnih (»bulk«) materialov in v obliki tankih filmov oz. nano objektov (nano žice, nano sfere, nano cevke) s poudarkom na motorski aplikaciji za ekološko energijo ter v medicini v nano-mehanizmih in prevlekah s posebnimi fizikalnimi lastnostmi.

Objectives and competences:

The students learn chemical (ELD, EPD), metallurgical and physical methods (melt-spinning, high energy milling, pulsed laser deposition) for processing of intermetallic magnetic and other complex alloys in bulk form and in the form of thin films and nano objects (rods, spheres, tubes) with the emphasis on the motor application for clean energy, medical application, as nano-devices, and coatings for special surface physical properties.

Predvideni študijski rezultati:

Znanje in razumevanje:
- Razumevanje mehanizmov sinteze kompleksnih intermetalnih zlitin, magnetnih tankih filmov in magnetnih nano objektov (žice, sfere, cevke).
- Poznavanje novih metod sinteze.
- Poznavanje metod karakterizacije kompleksnih intermetalnih zlitin, magnetnih tankih filmov in magnetnih nano objektov (žice, sfere, cevke).

Splošne kompetence:
- Obvladanje raziskovalnih metod, postopkov in procesov, razvoj kritične in samokritične presoje.
- Sposobnost uporabe znanja v praksi.
- Razvoj komunikacijskih sposobnosti in spretnosti, posebej komunikacije v mednarodnem okolju.
- Kooperativnost, delo v skupini (in v mednarodnem okolju).

Predmetnospecifične kompetence:
- Predmet pripravlja študente za delo na področju magnetnih in drugih intermetalnih kompleksnih zlitin s poudarkom na tankih magnetnih filmih, nano objektih (žice, sfere, cevke) in nanokristaliničnih prahovih.
- Predmet pripravlja študente na uporabo različnih metod procesiranja kompleksnih intermetalnih zlitin, tankih magnetnih filmov, nano objektov (žice, sfere, cevke) in

Intended learning outcomes:

Knowledge and understanding:
- The student will understand the mechanism of synthesis of complex intermetallic alloys, magnetic thin films and magnetic nano objects (wires, spheres, tubes).
- Knowledge of new methods of synthesis.
- Methods of characterization of magnetic and other physical properties in nano dimensions.

General Competences:
- The student will master research methods, procedures and processes in complex intermetallic alloys and nanomagnetism.
- The student will develop critical thinking.
- The student will develop communications skills to present research achievements in the international environment.
- Work in team (in international environment).

Course Specific Competences:
- This course prepares students to work on the field of magnetic and other complex intermetallic materials with the emphasis on thin films, nano objects (wires, spheres, tubes) and nanocrystalline powders.
- The course will give the students competence in the processing methods of complex intermetallic alloys, magnetic thin films, nano objects (wires, spheres, tubes) and nanocrystalline powders.
- The student will have competence in the

nanokristaliničnih prahov. • Študent bo razvil kompetence na področju karakterizacije kompleksnih intermetalnih zlitin, tankih magnetnih filmov, nano objektov (žice, sfere, cevke) in nanokristaliničnih prahov.	characterization of complex metallic alloys, magnetic thin films, nano objects (wires, spheres, tubes), and nanocrystalline powders.

Metode poučevanja in učenja:	**Learning and teaching methods:**
• Predavanja • Seminarji • Laboratorijsko delo • Obiski tovarn oz. organizacij s tematiko študija	• Lectures • Seminar work • Laboratory work • Visits of factories e.g. organizations with the thematic of the studies

Načini ocenjevanja:	Delež (v %) / Weight (in %)	**Assessment:**
Seminar	50 %	Seminar
Ustni izpit	50 %	Oral exam

Reference nosilca / Lecturer's references:

TOMŠE, Tomaž, JAĆIMOVIĆ, Jaćim, HERRMANN, Lozenz, GREUTER, Felix, REINHARD, Simon, TEKAVEC, Simona, DUBOIS, Jean-Marie, KOBE, Spomenka. Properties of SPS-processed permanent magnets prepared from gas-atomized Nd-Fe-B powders. *Journal of alloys and compounds*, ISSN 0925-8388. [Print ed.], [in press] 2018, 20 str., doi: 10.1016/j.jallcom.2018.01.411. [COBISS.SI-ID 31189799], [JCR, SNIP, Scopus do 24. 2. 2018: št. citatov (TC): 0, čistih citatov (CI): 0]

KELHAR, Luka, BEZJAK, Jana, MAČEK, Marjeta, ZAVAŠNIK, Janez, ŠTURM, Sašo, KOŽELJ, Primož, KOBE, Spomenka, DUBOIS, Jean-Marie. The role of Fe and Cu additions on the structural, thermal and magnetic properties of amorphous Al-Ce-Fe-Cu alloys. *Journal of non-crystalline solids*, ISSN 0022-3093. [Print ed.], [in press] 2017, 9 str., doi: 10.1016/j.jnoncrysol.2018.01.003. [COBISS.SI-ID 31059495], [JCR, SNIP, WoS do 24. 2. 2018: št. citatov (TC): 0, čistih citatov (CI): 0, Scopus do 3. 2. 2018: št. citatov (TC): 0, čistih citatov (CI): 0]

KOCJAN, Andraž, KELHAR, Luka, GRADIŠEK, Anton, LIKOZAR, Blaž, ŽAGAR, Kristina, GHANBAJA, Jaafar, KOBE, Spomenka, DUBOIS, Jean-Marie. Solid solubility in Cu5Gd1−xCax system : structure, stability, and hydrogenation. *Advances in Materials Science and Engineering*, ISSN 1687-8434. [Print ed.], 2017, vol. 2017, str. 9203623-1-9203623-9, doi: 10.1155/2017/9203623. [COBISS.SI-ID 30335527], [JCR, SNIP, WoS do 31. 3. 2017: št. citatov (TC): 0, čistih citatov (CI): 0, Scopus do 15. 4. 2017: št. citatov (TC): 0, čistih citatov (CI): 0]

NAGLIČ, Iztok, SAMARDŽIJA, Zoran, DELIJIĆ, Kemal, KOBE, Spomenka, DUBOIS, Jean-Marie, LESKOVAR, Blaž, MARKOLI, Boštjan. Metastable quasicrystals in Al-Mn alloys containing copper, magnesium and silicon. *Journal of Materials Science*, ISSN 0022-2461, 2017, vol. 52, no. 23, str. 13657-13668. https://link.springer.com/article/10.1007%2Fs10853-017-1477-8, doi: 10.1007/s10853-017-1477-8. [COBISS.SI-ID 1693279], [JCR, SNIP, WoS do 29. 9. 2017: št. citatov (TC): 0, čistih citatov (CI): 0, Scopus do 1. 3. 2018: št. citatov (TC): 1, čistih citatov (CI): 1]

PEČKO, Darja, KOSTEVŠEK, Nina, PIHLAR, Boris, SAMARDŽIJA, Zoran, KOBE, Spomenka, ŽUŽEK ROŽMAN, Kristina. Electrochemical studies of Fe and Pd deposition and their influence on the co-deposition of the Fe-Pd alloy. *Journal of electroanalytical chemistry*, ISSN 1572-6657, 2015, vol. 738, str. 51-60