NEKOVINSKI MATERIALI - RRP

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Nekovinski materiali - RRP
Course title:	Non-metallic materials - RRP
Članica nosilka/UL Member:	UL FS

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Strojništvo - razvojno raziskovalni program, prva stopnja, univerzitetni	Ni členitve (študijski program)	1. letnik	2. semester	obvezni

Univerzitetna koda predmeta/University course code:	0562745
Koda učne enote na članici/UL Member course code:	2008-U

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
45		30			50	5

Nosilec predmeta/Lecturer:	Alen Oseli, Lidija Slemenik Perše
Vrsta predmeta/Course type:	Obvezni splošni predmet /Compulsory general course

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

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	Prerequisites:
Izpolnjevanje pogojev za vpis v	Meeting the enrollment conditions for

Univerzitetni študijski program I. stopnje Strojništvo - Razvojno raziskovalni program.	the Academic study programme of Mechanical Engineering - Research and Development program.

Vsebina:	**Content (Syllabus outline):**
. Vsebina 1. Predavanja: ZGRADBA SNOVI in KEMIJSKE VEZI - Razdelitev snovi in njihove lastnosti, zakonitosti kemijskih sprememb, agregatna stanja, atomi, molekule, vrste in lastnosti kemijskih vezi, van der Waalsove interakcije. 2. Vsebina 2. Predavanja: LASTNOSTI in ZGRADBA TRDNIH SNOVI - Stehiometrija in IUPAC nomenklatura, periodni system, amorfna in kristalinična struktura, vpliv kristaliničnosti na mehanske lastnosti, kristali – zgradba, rast kristalov, napake v kristalni strukturi. 3. Vsebina 3. Predavanja: KEMIJSKA KINETIKA in KATALIZA - Kemijsko ravnotežje, Le Chatelierjev princip, hitrost in mehanizem reakcije (vpliv reaktantov, temperature in tlaka, agregatnega stanja, katalizatorjev), homogena in heterogena kataliza. 4. Vsebina 4. Predavanja: KEMIJSKE LASTNOSTI SNOVI in KEMIJSKI PROCESI v STROJNIŠTVU - Kisline in baze (pH), reaktivnost, topnost, gorljivost, procesi zgorevanja, degradacija snovi, zaščita nekovinskih materialov, procesi lepljenja. 5. Vsebina 5. Predavanja: POVEZAVA MED STRUKTURO IN LASTNOSTMI SNOVI - Strukturne lastnosti suspenzij, emulzij, makromolekul, osnove reologije – vpliv zunanje obremenitve na strukturne lastnosti nekovinskih materialov, razumevanje odziva materialov na podlagi določenih reoloških lastnosti. 6. Vsebina 6. Predavanja: ELEKTROKEMIJA - Osnove elektrokemije, redoks reakcije, redoks potenciali, termodinamika redoks reakcij, galvanski členi, elektroliza, uporaba elektrokemije	. Content of Lecture 1: MATERIAL STRUCTURE and CHEMICAL BONDS - Materials and their properties, characteristics of chemical changes, state of matter, atoms, molecules, types and properties of chemical bonds, van der Waals interactions. 2. Content of Lecture 2: PROPERTIES and STRUCTURE OF SOLIDS - Stoichiometry and IUPAC nomenclature, Periodic system, amorphous and crystalline structure, effect of crystallinity on mechanical properties, crystals - structure, growth, structural defects. 3. Content of Lecture 3: CHEMICAL KINETICS and CATALYSIS - Chemical equilibrium, Le Chatelier's principle, rate and mechanism of reaction (effect of reactants, temperature, pressure, state of matter, catalysts), homogeneous, heterogeneous catalysis. 4. Content of Lecture 4: CHEMICAL PROPERTIES and CHEMICAL PROCESSES in MECHANICAL ENGINEERING - Acids and bases (pH), reactivity, solubility, flammability, combustion, degradation, protection of non-metallic materials, bonding processes. 5. Content of Lecture 5: STRUCTURE - PROPERTY RELATIONSHIP - Structural properties of suspensions, emulsions, macromolecules, basic rheology - effect of external loading on structural properties of non-metallic materials, understanding the response of materials based on rheological properties. 6. Content of Lecture 6: ELECTROCHEMISTRY - Fundamentals of electrochemistry, redox reactions, redox potentials, thermodynamics of redox reactions,

v industriji. 7. Vsebina 7. Predavanja: KERAMIKA in STEKLO - Razdelitev in pregled osnovnih skupin nekovinskih materialov, osnovne značilnosti keramike in stekla, zgradba keramike; mikrostruktura keramičnih materialov, postopki izdelave keramike, stekla. 8. Vsebina 8. Predavanja: POLIMERNI MATERIALI - Definicije pojmov, značilnosti polimernih materialov, razdelitev polimerov v osnovne skupine, posebni polimerni materiali. 9. Vsebina 9. Predavanja: OSNOVE ORGANSKE KEMIJE in SINTETIČNI POLIMERI - Zgradba organskih spojin, ogljikovodiki, osnovne reakcije alkanov, alkenov, alkinov; osnovne skupine sintetičnih polimerov, lastnosti in primeri uporabe termoplastov, duroplastov, elastoplastov. 10. Vsebina 10. Predavanja: TERMIČNE ZNAČILNOSTI NEKOVINSKIH MATERIALOV - Fazni prehodi, karakteristične temperature prehodov, toplotni razteznostni koeficient, proces fizikalnega staranja, vpliv hitrosti segrevanja oz. ohlajanja na fazne prehode, koncept prostega volumna, metode za določitev termičnih lastnosti nekovinskih materialov. 11. Vsebina 11. Predavanja: NEKOVINSKI KOMPOZITI - Osnovne komponente in vrste kompozitnih struktur, vrste in lastnosti ojačitvenih komponent (vlakna, delci, nanodelci), vrste polimernih matric, postopki izdelave, računanje mehanskih lastnosti. 12. Vsebina 8. Predavanja: VISKOELASTIČNE LASTNOSTI NEKOVINSKIH MATERIALOV - Osnove viskoelastičnosti, teorija linearne viskoelastičnosti, mehanski modeli za popis viskoelastičnih odzivov, osnovne materialne funkcije, statične in dinamične materialne funkcije,	galvanic cells, electrolysis, application of electrochemistry in industry. 7. Content of Lecture 7: CERAMICS and GLASS - Basic groups of non-metallic materials, basic characteristics of ceramics and glass, structure and microstructure of ceramic materials, manufacturing processes of ceramics and glass. 8. Content of Lecture 8: POLYMERS - Basic definitions, characteristics of polymeric materials, basic groups of polymers, specific polymeric materials. 9. Content of Lecture 9: BASICS of ORGANIC CHEMISTRY AND SYNTHETIC POLYMERS - Structure of organic compounds, hydrocarbons, basic reactions of alkanes, alkenes, alkynes; basic groups of synthetic polymers, properties and use of thermoplastics, duroplasts, elastoplastics. 10. Content of Lecture 10: THERMAL CHARACTERISTICS OF NON-METALLIC MATERIALS - Phase transitions, characteristic transition temperatures, thermal expansion coefficient, physical aging, effect of heating or cooling rate on phase transitions, free volume concept, methods for determination of thermal properties of non-metallic materials. 11. Content of Lecture 11: NON-METALLIC COMPOSITES - Basic components and types of composite structures, types and properties of reinforcement components (fibers, particles, nanoparticles), types of polymer matrices, fabrication processes, calculation of mechanical properties. 12. Content of Lecture 12: VISCOELASTIC PROPERTIES of NON-METALLIC MATERIALS - Fundamentals of viscoelasticity, theory of linear viscoelasticity, mechanical models for the description of viscoelastic responses, basic material functions, static and dynamic material functions, Poisson number. 13. Content of Lecture 13: TIME-

Poissonovo število. 13. Vsebina 13. Predavanja: ČASOVNO-ODVISNE ZNAČILNOSTI POLIMERNIH MATERIALOV - Časovno odvisno mehansko vedenje polimerov, materialne (prenosne) funkcije (statične in dinamične), fizikalno ozadje procesov lezenja in relaksacije, mehanski spekter materiala (relaksacijski, retardacijski), fizikalni pomen mehanskega spektra. 14. Vsebina 14. Predavanja: VPLIV TEMPERATURE, TLAKA in VLAGE NA ČASOVNO-ODVISNO MEHANSKO VEDENJE POLIMERNIH MATERIALOV - Vpliv vlage, temperature in tlaka na mehanske lastnosti, eksperimentalne metode in principi karakterizacije časovno odvisnega vedenja polimerov: Boltzmanov superpozicijski princip, izohrone, sumarna krivulja, premaknitveni faktorji, WLF enačba, Doolitle enačba. 15. Vsebina 15. Predavanja: RECIKLIRANJE POLIMERNIH MATERIALOV - Vrste recikliranja, vpliv strukture na izbiro postopka recikliranja, vpliv recikliranja na termične, strukturne in mehanske lastnosti.	DEPENDENT CHARACTERISTICS of POLYMER MATERIALS - Time dependent mechanical behavior of polymers, material (transfer) functions (static and dynamic), physical background of creep and relaxation processes, material mechanical spectrum (relaxation, retardation), physical significance of mechanical spectrum. 14. Content of Lecture 14: The EFFECT of TEMPERATURE, PRESSURE and MOISTURE on the TIME-DEPENDENT MECHANICAL BEHAVIOUR of POLYMER MATERIALS - The effect of moisture, temperature and pressure on mechanical properties, experimental methods and principles of characterization of the time-dependent behavior of polymers: Boltzmann superposition principle, isochrones, master curves, shift factors, WLF equation, Doolitle equation. 15. Content of Lecture 15: RECYCLING of POLYMER MATERIALS - Types of recycling processes, the impact of structure on the selection of the recycling process, the impact of recycling on thermal, structural and mechanical properties.

Temeljna literatura in viri/Readings:

1. F. Lazarini in J. Brenčič: Splošna in Anorganska kemija, Založba FKKT, Ljubljana 1989, [COBISS.SI-ID 8362496]
2. Atkins, Peter William, De Paula, Julio, Atkins' physical chemistry, Oxford [etc.] : Oxford University Press, cop. 2006, ISBN - 0-19-870072-5, [COBISS.SI-ID 27638277]
3. Ferry J.D.: Viscoelastic properties of polymers. John Wiley & Sons, 1980, ISBN - 0-471-04894-1, [COBISS.SI-ID 139823].
4. Ward I.M., and John Sweeney. Mechanical properties of solid polymers. John Wiley & Sons, 2012, ISBN - 0-471-91995-0, [COBISS.SI-ID 141289].
5. McCrum N.G., Buckley C.P., Bucknall C.B., Principles of Polymer Engineering, Oxford University Press, New York, 1997, ISBN - 978-0-19-856526-0, [COBISS.SI-ID 16337179].

Cilji in kompetence:	**Objectives and competences:**
Cilji: 1. Cilj 1: spoznati pomen kemije v	Aims: 1. Aim 1: to understand the importance

inženirstvu s poudarkom na realnih primerih v strojništvu 2. Cilj 2: spoznati povezavo poznavanja zgradbe snovi in njen vpliv na kemijske in fizikalne lastnosti materiala 3. Cilj 3: spoznati lastnosti nekovinskih materialov pri različnih okoljskih pogojih 4. Cilj 4: spoznati lastnosti nekovinskih materialov pri različnih pogojih obremenjevanja 5. Cilj 5: spoznati pomen trajnostnega razvoja Kompetence: 1. Kompetenca 1: sinteza osnov kemije v strojniške aplikacije (S6-RRP + P1-RRP) 2. Kompetenca 2: sposobnost analize zgradbe snovi ter njenega vpliva na kemijske in fizikalne lastnosti materiala (S1-RRP, S8-RRP + P2-RRP) 3. Kompetenca 3: sposobnost napovedovanja vedenja nekovinskih materialov pri različnih okoljskih pogojih (S7-RRP + P3-RRP) 4. Kompetenca 4: sposobnost napovedovanja vedenja nekovinskih materialov pri različnih pogojih obremenjevanja (S2-RRP + P6-RRP) 5. Kompetenca 5: sposobnost izbire ustreznega postopka predelave po končani življenjski dobi izdelka (S9-RRP + P5-RRP)	of chemistry in engineering with a focus on real-life examples in mechanical engineering 2. Aim 2: to understand the connection between the structure and the chemical and physical properties of the material 3. Aim 3: to learn about the properties of non-metallic materials under different environmental conditions 4. Aim 4: to learn about the properties of non-metallic materials under various loading conditions 5. Aim 5: to understand the importance of sustainable development Competences: 1. Competence 1: the ability to use the basic knowledge of chemistry in mechanical engineering (S6-RRP + P1-RRP) 2. Competence 2: the ability to analyze the structure of the material and its effect on the chemical and physical properties (S1-RRP, S8-RRP + P2-RRP) 3. Competence 3: the ability to predict the behavior of non-metallic materials under different environmental conditions (S7-RRP + P3-RRP) 4. Competence 4: the ability to predict the behavior of non-metallic materials under different loading conditions (S2-RRP + P6-RRP) 5. Competence 5: the ability to select the appropriate recycling process after the end of the product's lifetime (S9-RRP + P5-RRP)

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanja: Z1: Poglobljeno strokovno teoretično in praktično znanje kemije v inženirstvu s poudarkom na dejanskih realnih primerih snovi in nekovinskih materialov v strojništvu. Osnovno znanje kemije s povezavo poznavanja zgradbe snovi in njen vpliv na kemijske ter fizikalne lastnosti materiala.	Knowledge: Z1: In-depth theoretical and practical knowledge of chemistry in engineering with a focus on actual real-life examples of non-metallic materials in mechanical engineering. Basic knowledge of chemistry with relation between the knowledge of structure and its effect on chemical and physical properties of

Poglobljeno strokovno teoretično in praktično znanje na področju vedenja nekovinskih materialov pri različnih okoljskih vplivih in obremenitvah. Spretnosti: 1. S1 Izvajanje kompleksnih karakterizacijskih tehnik in metod za določevanje različnih lastnosti nekovinskih materialov. 2. S1.2 Obvladovanje zahtevnih, kompleksnih lastnosti nekovinskih materialov ob samostojni uporabi pridobljenega znanja v realnih delovnih situacijah. 3. S1.3 Diagnosticiranje in reševanje problemov uporabe nekovinskih materialov v industrijskih procesih na področju strojništva. 4. S1.4 Osnova za izvirne rešitve napak nekovinskih produktov oz. tehnoloških procesov predelave nekovinskih materialov ter kritično refleksijo.	material. In-depth theoretical and practical knowledge of the behavior of non-metallic materials at various environmental impacts and loads. Skills: 1. S1 Implementation of complex characterization techniques and methods for determination of various properties of non-metallic materials. 2. S1.2 Mastering demanding and complex properties of non-metallic on the basis of creative use of acquired knowledge in specialised professional fields. 3. S1.3 Solving problems of using non-metallic materials in industrial processes. 4. S1.4 Ability of unique solutions in technological processes and critical reflections.

Metode poučevanja in učenja:	**Learning and teaching methods:**
1. Metoda 1: Klasične oblike poučevanja: P1 Avditorna predavanja z reševanjem izbranih - za področje značilnih - teoretičnih in praktično uporabnih primerov. P2 Obravnava snovi po urejeni in vnaprej razloženi sistematiki. P5 Uporaba študijskega gradiva v obliki skripta, e-verzija predstavitve predavanj P9 Skupinsko delo (razprave za – proti, strukturirana diskusija, viharjenje možganov) 2.Metoda 2: Moderne in prožne oblike poučevanja: P10 Uporaba anket v realnem času P14 Virtualni eksperimenti P15 Uporaba video vsebin kot priprava na predavanja	1. Method 1: Conventional teaching methods: P1 Auditorial lectures with solving selected field-specific theoretical and applied use cases. P2 Presenting the content according to the explained system. P5 Application of study material (textbook, e-book of the lectures). P9 Team work (discussions pro and contra, structured discussion, brainstorming) 1. Method 2: Contemporary and flexible teaching methods: P10 Application of questionaries in real time. P14 Virtual experiments. P15 Application of videos for preparations to the lectures and exercises.

Načini ocenjevanja:	Delež/ Weight	Assessment:
- Teoretične vsebine (predavanja).	60,00 %	- Theoretical part (lectures).
- Samostojno delo na vajah.	20,00 %	- Individual work during laboratory practice.
- Delo na laboratorijskih vajah (vključno s poročili).	20,00 %	- Laboratory work (report included).

Ocenjevalna lestvica:	Grading system:

Reference nosilca/Lecturer's references:

Lidija Slemenik Perše:

1. HAJZERI, Metka, **SLEMENIK PERŠE, Lidija**, KOŽELJ, Matjaž, OREL, Boris, SURCA, Angelja Kjara. Structural investigation of ormolytes for EC devices : IR spectroscopic characterization and relation between viscoelastic properties, conductivity and optical modulation. Solar energy materials and solar cells, ISSN 0927-0248. [Print ed.], Aug. 2015, vol. 139, str. 51-64. [COBISS.SI-ID 5675802]
2. BEK, Marko, AULOVA, Alexandra, PUŠNIK ČREŠNAR, Klementina, MATKOVIČ, Sebastjan, KALIN, Mitjan, **SLEMENIK PERŠE, Lidija**. Long-term creep compliance of wood polymer composites: using untreated wood fibers as a filler in recycled and neat polypropylene matrix. Polymers. June 2022, vol. 14, iss. 13 (2539), 19 str., ilustr. ISSN 2073-4360. https://repozitorij.uni-lj.si/IzpisGradiva.php?id=137942, https://dk.um.si/IzpisGradiva.php?id=82068, DOI: 10.3390/polym14132539. [COBISS.SI-ID 113069315]
3. SHANKAR VADIVEL, Hari, BEK, Marko, ŠEBENIK, Urška, **SLEMENIK PERŠE, Lidija**, KÁDÁR, Roland, EMAMI, Nazanin, KALIN, Mitjan. Do the particle size, molecular weight, and processing of UHMWPE affect its thermomechanical and tribological performance?. Journal of Materials Research and Technology. May-Jun. 2021, vol. 12, str. 1728-1737, ilustr. ISSN 2238-7854. https://www.sciencedirect.com/science/article/pii/S2238785421003148, https://repozitorij.uni-lj.si/IzpisGradiva.php?id=126861, DOI: 10.1016/j.jmrt.2021.0087. [COBISS.SI-ID 59130883]
4. OPARA KRAŠOVEC, Urša, VIDMAR, Tjaša, KLANJŠEK GUNDE, Marta, CERC KOROŠEC, Romana, **SLEMENIK PERŠE, Lidija**. In-depth rheological characterization of tungsten sol-gel inks for inkjet printing. Coatings. 2022, vol. 12, iss. 2, 15 str., ilustr. ISSN 2079-6412. https://www.mdpi.com/2079-6412/12/2/112, https://dirros.openscience.si/IzpisGradiva.php?id=14744&lang=slv, https://repozitorij.uni-lj.si/IzpisGradiva.php?id=137098, https://dirros.openscience.si/IzpisGradiva.php?id=14744, DOI: 10.3390/coatings12020112. [COBISS.SI-ID 96639491]
5. AULOVA, Alexandra, BEK, Marko, **SLEMENIK PERŠE, Lidija**. Effect of calendering temperatures on mechanical properties of polypropylene foils. V:

Book of abstract : MTDM 2018. The 11th International Conference on the Mechanics of Time Dependent Materials, September 4th-7th, 2018. [COBISS.SI-ID 16267035]

Alen Oseli:

1. **OSELI, Alen**, TOMKOVIĆ, Tanja, HATZIKIRIAKOS, Savvas G., VESEL, Alenka, ARZENŠEK, Matija, ROJAC, Tadej, MIHELČIČ, Mohor, SLEMENIK PERŠE, Lidija. Carbon nanotube network formation and configuration/morphology on reinforcing and conductive performance of polymer-based nanocomposites. *Composites science and technology*. 26 May 2023, vol. 237, [article no.] 110010, str. 1-9, ilustr. ISSN 1879-1050. https://www.sciencedirect.com/science/article/pii/S0266353823001033, https://repozitorij.uni-lj.si/IzpisGradiva.php?id=145001, DOI: 10.1016/j.compscitech.2023.110010. [COBISS.SI-ID 147041027]
2. **OSELI, Alen**, VESEL, Alenka, ŽAGAR, Ema, SLEMENIK PERŠE, Lidija. Mechanisms of single-walled carbon nanotube network formation and its configuration in polymer-based nanocomposites. *Macromolecules*. Apr. 2021, vol. 54, iss. 7, str. 3334-3346, ilustr. ISSN 0024-9297. https://pubs.acs.org/doi/10.1021/acs.macromol.0c02763#, https://repozitorij.uni-lj.si/IzpisGradiva.php?id=126692, DOI: 10.1021/acs.macromol.0c02763. [COBISS.SI-ID 58206467]
3. AULOVA, Alexandra, **OSELI, Alen**, BEK, Marko. Neural networks for predicting the temperature-dependent viscoelastic response of PEEK under constant stress rate loading. *Polymer testing*. [Print ed.]. Aug. 2021, vol. 100, str. 1-9, ilustr. ISSN 0142-9418. https://www.sciencedirect.com/science/article/pii/S0142941821001835?via%3Dihub, https://repozitorij.uni-lj.si/IzpisGradiva.php?id=127412, DOI: 10.1016/j.polymertesting.2021.107233. [COBISS.SI-ID 65892867]
4. **OSELI, Alen**, VESEL, Alenka, MOZETIČ, Miran, ŽAGAR, Ema, HUSKIĆ, Miroslav, SLEMENIK PERŠE, Lidija. Nano-mesh superstructure in single-walled carbon nanotube/polyethylene nanocomposites, and its impact on rheological, thermal and mechanical properties. *Composites. Part A, Applied science and manufacturing*. [Print ed.]. Sep. 2020, vol. 136, str. 1-10, ilustr. ISSN 1359-835X. https://www.sciencedirect.com/science/article/pii/S1359835X20302116?dgcid=author, https://repozitorij.uni-lj.si/IzpisGradiva.php?id=116530, DOI: 10.1016/j.compositesa.2020.105972. [COBISS.SI-ID 17053187]
5. **OSELI, Alen**, VESEL, Alenka, MOZETIČ, Miran, ŽAGAR, Ema, HUSKIĆ, Miroslav, SLEMENIK PERŠE, Lidija. Nano-mesh formation in single-walled carbon nanotube / polyethylene nanocomposites and its effect on their physical properties. V: *COST Action CA15107 MultiComp, Multi-functional Nano-Carbon Composite Materials Network : Final Multicomp Meeting 2020, 24th - 25th September, 2020 Slovenj Gradec, Slovenia : [book of abstract]*. [Slovenj Gradec: Faculty of Polymer Technology, 2020]. Str. 14, ilustr. https://www.ftpo.eu/Portals/0/Multicomp_Book_of_Abstracts-SG-2020.pdf. [COBISS.SI-ID 32596483]