UČNI NAČRT PREDMETA / COURSE SYLLABUS	
Predmet:	Vakuumistika
Course title:	Vacuum Science and Technology

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:	NANO3-839

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. Janez Kovač Prof. dr. Miran Mozetič

Jeziki /	**Predavanja / Lectures:**	Slovenski ali angleški / Slovene or English
Languages:	**Seminar:**	Angleški / English

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	**Prerequisits:**
Zaključen študij druge stopnje naravoslovne ali tehniške smeri ali zaključen študij drugih smeri z dokazanim poznavanjem 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):**
Fizikalne osnove, izrazoslovje, merilne enote in definicije v vakuumski tehniki in tehnologiji. Priprava vakuuma: črpanje plinov, vakuumske črpalke, hitrost črpanja, vrste pretokov plinov. Fizikalno-kemijski procesi na površinah materialov: desorpcija, adsorpcija, sorpcija, segregacija, difuzija, permeacija, razplinjanje materialov. Meritve vakuuma od 1000 mbar do 10-12 mbar, izbira merilnikov tlaka, principi meritev, analiza preostalih plinov z masno spektrometrijo, detekcija puščanja, hitrost puščanja.	Introduction in vacuum physics, basic terms, units of measurement, definitions in vacuum techniques and technology. Vacuum generation: pumping of gases, vacuum pumps, pumping speed, types of gas flow. Physical-chemical processes at the surfaces of materials: desorption, absorption, sorption, segregation, diffusion, permeation, outgassing. Vacuum measurement in the range from 1000 mbar to 10-12 mbar, selection of vacuum gauges, analysis of residual gases using mass spectrometry,

Vakuumske komponente, sistemi in materiali: načrtovanje vakuumskega sistema glede na področje vakuuma; izbira materialov in komponent. Metode za analizo površin, ki delujejo v ultravisokem vakuumu: rentgenska fotoelektronska spektroskopija (XPS), masna spektrometrija sekundarnih ionov (SIMS), spektroskopija Augerjevih elektronov (AES): fizikalni principi, analizna globina, lateralna ločljivost, občutljivost metod, kvantitativna obdelava podatkov, profilna analiza tankih plasti. Nizkotlačne in atmosferske plazme: termodinamsko neravnovesno stanje plinov, uporaba plazme za čiščenje, aktivacijo, funkcionalizacijo in selektivno jedkanje površin. Vakuumska tehnika v inženirstvu površin za izboljšanje lastnosti površin: priprava in obdelava površin, nanos PVD in CVD prevlek. Vakuumske tehnologije v metalurgiji, kemijski, farmacevtski, prehrambni industriji, elektroniki in elektrooptiki.	detection of leaks, leak rate. Vacuum components, systems and materials, design of vacuum systems for different ranges, selection of materials and components. Surface analytical techniques based on ultrahigh vacuum: X-ray photoelectron spectroscopy (XPS), Secondary ion mass spectroscopy (SIMS), Auger electron spectroscopy (AES), physical principles, sampling depth, spatial resolution, sensitivity, quantification, data processing, depth profiling of thin films. Low pressure and atmospheric plasmas: thermodynamically non-equilibrium state of gas, applications for cleaning, surface activation, surface functionalization and selective etching. Vacuum techniques in surface engineering: to improve performance of materials: surface preparation and treatment, deposition of PVD and CVD coatings. Vacuum technologies in metallurgy, pharmaceutic and food industry, electronics and optoelectronics.

Temeljni literatura in viri / Readings:

Izbrana poglavja iz naslednjih knjig in virov: / Selected chapters from the following books:

1. V. Nemanič (urednik): Vakuumska znanost in tehnika, Društvo za vakuumsko tehniko Slovenije, Ljubljana, 2003.
2. Pedagoški material pri Mednarodni zvezi za vakuumsko znanost, tehniko in aplikacije – IUVSTA: http://www.iuvsta-us.org/iuvsta2/index.php?id=2072, urednik M. Mozetič, 2013
3. Vacuum Technology Book, Volume II, Pfeiffer Vacuum GmbH, 2018, https://www.pfeiffer-vacuum.com/en/info-center/vacuum-technology-book/
4. J. Gasperič: Nasveti za uporabnike vakuumske tehnike, Društvo za vakuumsko tehniko Slovenije, Ljubljana, 2002.
5. P. Panjan, M. Čekada, Zaščita orodij s trdimi PVD-prevlekami, Institut »Jožef Stefan«, 2005
6. J. M. Lafferty (editor): Foundations of Vacuum Science and Technique, John Wiley and Sons, Inc., New York, (1998).
7. M. Wutz, H. Adam, W. Walcher: Theory and Practice of Vacuum Technology, Third Edition Friedr. Vieweg and Son. Braunschweig, (1989).
8. S. Hofmann, Auger- and X-Ray Photoelectron Spectroscopy in Material Science, Springer-Verlag Berlin Heidelberg, 2013
9. D. Briggs, J. T. Grant (eds.): Surface Analysis by Auger and X-Ray Photoelectron Spectroscopy, IM Publications, Chichester, 2003.
10. M. Thomas, K. L. Mittal (eds.), Atmospheric Pressure Plasma Treatment of Polymers, John Wiley and Sons and Scrivener Publishing LLC, Salem, Massachusetts, 2013
11. Marija Gorjanc, Miran Mozetič: Modification of fibrous polymers by gaseous plasma: principles,

techniques and applications. Saarbrücken: LAP Lambert Academic Publishing, 2014.

Cilji in kompetence:	**Objectives and competences:**
Cilj predmeta je, da študenti spoznajo in razumejo osnove vakuumske tehnike in tehnologije, na nekaterih področjih pa znajo aktivno uporabljati dobljena znanja in reševati probleme. Študenti bodo zmožni uporabljati znanje o pripravi in merjenju vakuuma, vakuumskih komponentah, načrtovanju in izgradnji vakuumskega sistema, o detekciji puščanja in o vakuumskih materialih. Študenti bodo spoznali pripravo tankih plasti iz parne faze v vakuumu in obdelavo materialov s plinsko plazmo. Študenti bodo razumeli fizikalno-kemijske osnove o reaktivni plazmi, kot so čiščenje, aktivacija, funkcionalizacija površin ter selektivno jedkanje. Študenti bodo zmožni uporabljati moderne analizne metode za preiskavo površin in tankih plasti, ki temeljijo na vakuumu. Zmožni bodo primerjalne analize dobljenih podatkov in reševanja problemov, povezanih s površinami materialov.	Students will gain knowledge on fundamentals of vacuum techniques and technology. On some topics they will be able to use this knowledge actively and solve the problems. The students will be able to use a knowledge on vacuum generation, vacuum measurement, vacuum components, design and realization of vacuum systems, detection of leaks and use of vacuum materials. Students will get knowledge about physical vapour deposition of thin films and plasma treatment of surfaces. Students will understand physical and chemical properties of reactive plasmas for treatments of like cleaning, surface activation, surface functionalization and selective etching. Students will be able to use surface analytical methods based on vacuum. They will be able to choose the most suitable method, evaluate and compare the obtained results and solve the problems related to materials surfaces.

Predvideni študijski rezultati (izidi):	**Intended learning outcomes:**
Študenti bodo razumeli procese, ki potekajo v vakuumskem okolju. Študenti bodo sposobni uporabiti osnovne parametre za opis vakuumskega sistema. Študenti bodo sposobni načrtovati, izbrati primerni material in komponente ter sestaviti vakuumski sistem. Študenti bodo sposobni prepoznati procese na površinah sten vakuumskih posod. Študenti bodo spoznali različne vakuumske tehnologije, ki so najbolj pogosto uporabljene v industriji in izbrati najbolj primerno za specifični problem. Študenti bodo znali izbrati primerno metodo za karakterizacijo površin, tankih plasti in vakuumske atmosfere, uporabiti to metodo in ovrednotiti rezultate teh metod.	The students will understand the basic physical processes in the vacuum ambient. Students will be able to use basic parameters to describe the vacuum systems. Students will be able to design, choose the suitable material and components and integrate the vacuum system. Students will be able to identify processes on the surfaces of the walls inside of the vacuum vessels. Students will learn about different vacuum technologies most often applied in different industrial fields and choose the most suitable technology for specific problem. Students will be able to choose the proper analytical method for characterization of surfaces, thin films and vacuum atmosphere, to use this method and evaluate the results.

Študenti bodo razumeli osnove plazemskih interakcij, znali bodo izbrati primerno plazemsko obdelavo za modifikacijo površin, jo uporabiti in ovrednotiti rezultate.	Students will understand basic plasma interactions, choose the proper plasma treatment for surface modification, apply it and evaluate results.

Metode poučevanja in učenja:	**Learning and teaching methods:**
Predavanja Konzultacije Seminarji Laboratorijsko delo	Lectures Consultancy Seminar work Laboratory work

Načini ocenjevanja:	Delež (v %) / Weight (in %)	**Assessment:**
Ustni izpit	50 %	Oral exam
Seminarska naloga	25 %	Seminar work
Zagovor seminarske naloge, pri katerem dokaže osvojitev vseh študijskih izidov z vsaj po enim konkretnim primerom	25 %	Defense of the seminar work where the student demonstrates the achievement of all learning outcomes with at least one specific case for each outcome

Reference nosilca / Lecturer's references:

1. G. Žerjav, M.S. Arshad, P. Djinović, I. Junkar, J. Kovač, J. Zavašnik, A. Pintar, Improved electron-hole separation and migration in anatase TiO_2 nanorod/reduced graphene oxide composites and their influence on photocatalytic performance, Nanoscale, 2017, vol. 9, iss. 13, str. 4578-4592.
2. U. Tiringer, J. Kovač, I. Milošev, Effects of mechanical and chemical pre-treatments on the morphology and composition of surfaces of aluminium alloys 7075-T6 and 2024-T3, *Corrosion science,* 2017, vol. 119, str. 46-59.
3. H. Puliyalil, G. Filipič, J. Kovač, M. Mozetič, S. Thomas, U. Cvelbar, Tackling chemical etching and its mechanisms of polyphenolic composites in various reactive low temperature plasmas, RSC advances, 2016, vol. 6, iss. 97, str. 95120-95128.
4. A.Vesel, A. Drenik, K. Eleršič, M. Mozetič, J. Kovač, T. Gyergyek, J. Stöckel, J. Varju, R. Panek, M. Balat-Pichelin, Oxidation of Inconel 625 superalloy upon treatment with oxygen or hydrogen plasma at high temperature, Applied Surface Science, vol. 305, 674-682.
5. Miran Mozetič et al., Recent advances in vacuum sciences and applications, J. Phys. D: Appl. Phys. 47 (2014) 153001.