UČNI NAČRT PREDMETA / COURSE SYLLABUS	
Predmet:	Detekcija vodika v materialih in v plinasti fazi
Course title:	Hydrogen Detection in Materials and in Gas Phase

Študijski program in stopnja Study programme and level	Študijska smer Study field	Letnik Academic year	Semester Semester
Senzorske tehnologije, 3. stopnja	/	1	1
Sensor technologies, 3rd cycle	/	1	1

Vrsta predmeta / Course type Izbirni / Elective

Univerzitetna koda predmeta / University course code: ST3-540

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. Sabina Markelj

Jeziki / Languages:	
Predavanja / Lectures:	Slovenski ali angleški / Slovene or English
Vaje / Tutorial:	Slovenski ali angleški / Slovene or English

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

Zaključen študij druge stopnje ustrezne (naravoslovne ali tehniške) smeri ali zaključen študij drugih smeri z dokazanim poznavanjem osnov področja predmeta (pisna dokazila, pogovor).

Prerequisits:

Completed second cycle studies in natural sciences or engineering or completed second cycle studies in other fields with proven knowledge of fundamentals in the field of this course (certificates, interview).

Vsebina:

- Vodik – atom/molekula: energijski potenciali, ionizacijski preseki.
- Interakcija vodika z materiali: procesi na površini, adsorpcija in absorpcija v material, difuzija, termodesorpcija.
- Detekcija vodikovih molekul in atomov: produkcija atomov in vzbujenih molekul, izvori, spektrometri, masni spektrometer.
- Detekcija vodika in njegovih izotopov v materialih z ionskimi metodami: spektroskopija elastično odrinjenih jeder – ERDA; spektroskopija z jedrsko metodo NRA; spremljanje procesov in situ.

Content (Syllabus outline):

- Hydrogen – atom/molecule: potential energy, cross sections for ionization.
- Interaction of hydrogen with materials: surface processes, adsorption, absorption in material, diffusion, thermal desorption.
- Hydrogen atom and molecule detection: production of atoms and excited molecules, sources, spectrometers, mass spectrometer.
- Hydrogen detection in materials with ion beam methods: Elastic Recoil Detection Analysis – ERDA; Nuclear Reaction Analysis – NRA; in situ measurements.
- Surface techniques for detection of hydrogen and surface impurities.

• Površinske tehnike za detekcijo vodika in nečistoč na površini. • Vodik v fuziji: zadrževanje in recikliranje vodika na stenah fuzijskih naprav.	• Hydrogen in fusion: retention and recycling of hydrogen on walls of fusion devices.

Temeljni literatura in viri / Readings:

Izbrani znanstveni članki v / Selected scientific publications in:

- Surface Science
- Journal of Chemical Physics
- Nuclear Instruments and Methods in Physics Research Section B
- Journal of Nuclear Material

Knjiga/book:

- Dynamics of molecule surface interactions, G. D. Billing, John Willey and Sons, 2000, New York.
- Handbook of Modern Ion Beam Materials Analysis, Y. Wang, M. Nastasi, Cambridge University Press, 2010.

Cilji in kompetence:	**Objectives and competences:**
Cilji: • poznavanje in razumevanje procesov pri interakciji vodika z materiali, • analiza podatkov, merjenih s spektrometri za detekcijo vodika, npr. masnim spektrometrom, vibracijskim spektrometrom, • analiza podatkov, merjenih z ionskimi metodami (ERDA in NRA), s katerimi določimo vsebnost vodika v materialu. Kompetence: • opredelitev procesov, ki so bistveni za določen primer interakcije vodika z materialom in reševanje enačbe za izbrani problem, • obvladovanje osnovnega orodja za simulacijo in analizo spektra, dobljenega iz spektrometra za detekcijo vodika in spektra, dobljenega z ionskimi metodami, • sposobnost izbiranja metod, s katerimi bi dobili potrebno informacijo o vodiku v materialu, • upoštevanje danih sistemskih, tehnoloških in finančnih okvirov pri snovanju analize materiala, • sposobnost izvedbe eksperimentalnih meritev na enem od možnih sistemov za detekcijo vodika in analiza podatkov z dosegljivimi orodji.	Objectives: • knowledge and understanding the processes at hydrogen interaction with materials, • analysis of the data measured by spectrometers for hydrogen detection, e.g. mass spectrometer, vibrational spectrometer, • analysis the data measured by ion beam methods (ERDA and NRA) used to quantify the hydrogen concentration in material. Competences: • capability to determine the relevant processes for certain case of hydrogen interaction with material and to solve equations for given problem, • mastering of software for simulation and analysis of spectra obtained by spectrometer for hydrogen detection and spectra obtained by ion beam methods, • capability of choosing the most suitable method(s) for obtaining the needed information about hydrogen in material, • applying project-given technological, systemic, temporal and financial constraints for the material analysis, • ability of performing experimental measurement on one of the possible systems for hydrogen detection and analyses the data with the available tools.

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanje in razumevanje: • detekcijskih metod kot so termodesorpcija, vibracijska spektroskopija, ionske metode za detekcijo vodika v materialih, • razumevanje procesov pri interakciji atomov in molekul z materiali, • vodika v fuziji, • vključevanje teh dosežkov v reševanje problemov v sklopu disertacije.	Knowledge and understanding of: • detection methods such as thermal desorption, vibrational spectroscopy, ion methods for hydrogen detection in materials, • understanding of processes at hydrogen atom and molecule interaction with materials, • hydrogen in fusion, • integration of these achievements in solving problems within the framework of the thesis.

Metode poučevanja in učenja:	**Learning and teaching methods:**
Interaktivno delo s študentom. Učenje prepoznavanja struktur in vzorcev znanja in reševanje realnih problemov.	Interactive work with student. Knowledge structures and pattern recognition, and solving real problems.

Načini ocenjevanja:	Delež (v %) / Weight (in %)	**Assessment:**
Seminarska naloga z opisom izbrane spektroskopije in njenih aplikacij, po možnosti iz problematike, ki je najbližje kandidatovemu raziskovalnemu področju.	30 %	Seminar describing particular spectroscopy and its applications in a research field close to the candidate.
Projekt kvantitativne analize spektra.	20 %	Project of quantitative analysis of spectrum.
Ustni izpit.	50 %	Oral examination.

Reference nosilca / Lecturer's references:

- Markelj S., Schwarz-Selinger T., Založnik A. (2017) Hydrogen isotope accumulation in the helium implantation zone in tungsten. *Nuclear Fusion,* 57(6), 064002-1-064002-5, doi: 10.1088/1741-4326/aa6b27.
- Markelj S., Schwarz-Selinger T., Založnik A., Kelemen M., Vavpetič P., Pelicon P., Hodille E. A., Grisolia C. (2017) Deuterium retention in tungsten simultaneously damaged by high energy W ions and loaded by D atoms. *Nuclear Materials and Energy*, 12, 169-174, doi: 10.1016/j.nme.2016.11.010.
- Brezinšek S.,..Markelj S., et al. (2017) Plasma-wall interaction studies within the EUROfusion Consortium: progress on plasma-facing components development and qualification. *Nuclear Fusion*, 57(11), 116041-1-116041-9, ilustr. http://iopscience.iop.org/article/10.1088/1741-4326/aa796e/meta, doi: 10.1088/1741-4326/aa796e.
- Markelj S., Založnik A., Schwarz-Selinger T., Ogorodnikova O., Vavpetič P., Pelicon P., Čadež I. (2016) In-situ NRA study of hydrogen isotope exchange in self-ion damaged tungsten exposed to fuel atoms. *Journal of Nuclear Materials*, 469, 133-144, doi: 10.1016/j.jnucmat.2015.11.039.
- Ogorodnikova O., Markelj S., Toussaint Udo von. (2016) Interaction of atomic and low-energy deuterium with tungsten pre-irradiated with self-ions. *Journal of Applied Physics*, 119(5), 054901-1-054901-9, doi: 10.1063/1.4940678.