

MIKROIZDELOVALNE TEHNOLOGIJE

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Mikroizdelovalne tehnologije
Course title:	Micromanufacturing technologies
Članica nosilka/UL Member:	UL FS

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Strojništvo - Razvojno raziskovalni program, druga stopnja, magistrski	Proizvodno strojništvo (smer)	1. letnik	1. semester	obvezni

Univerzitetna koda predmeta/University course code:	0566829
Koda učne enote na članici/UL Member course code:	6044-M

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
30		30			65	5

Nosilec predmeta/Lecturer:	Joško Valentinčič
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Izvajalci predavanj:	
Izvajalci seminarjev:	
Izvajalci vaj:	
Izvajalci kliničnih vaj:	
Izvajalci drugih oblik:	
Izvajalci praktičnega usposabljanja:	

Vrsta predmeta/Course	Obvezni strokovni predmet na smeri Proizvodno
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type:

strojništvo, ki je izbirni strokovni predmet na ostalih smereh./Compulsory specialised course in the study of Production Engineering, which is an elective specialised course in other fields of study.

Jeziki/Languages:

Predavanja/Lectures:	Slovenščina
Vaje/Tutorial:	Slovenščina

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

Zaključena 1. stopnja.	Finished bachelor study programme.
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Vsebina:**Content (Syllabus outline):**

<p>1. Uvod:</p> <ul style="list-style-type: none"> - definicija mikroizdelkov, mikroizdelovalnih procesov in mikroizdelovalnih verig; - mikrosistemske in mikroinženirske tehnologije; - posebnosti na področju mikroizdelave; - izdelki in tržišče; - mikrofluidni sistemi. <p>2. Kemijski principi nanašanja in odnašanja materiala:</p> <ul style="list-style-type: none"> - primeri na področju mikrosistemskih in mikroinženirskih tehnologij; - mikrosistemske tehnologije: materiali; - mono- in polikristali; - nekateri postopki suhega in mokrega jedkanja; - izbira primerne postopka; - primeri izdelkov. <p>3. Mikrosistemske tehnologije:</p> <ul style="list-style-type: none"> - izdelava v polno; - površinska izdelava; - postopek LIGA; lasersko direktno zapisovanje: CAD-CAM, obdelovalni parametri, fotopolimeri in jedkala; - primeri izdelkov. <p>4. Mikroelektrokemijsko dolbenje:</p> <ul style="list-style-type: none"> - mehanizem anodnega raztapljanja, osnovne enačbe odnašanja materiala; - krmiljenje procesa; - značilnosti obdelave; 	<p>1. Introduction:</p> <ul style="list-style-type: none"> - definition of micro-products, micro-manufacturing processes and micromanufacturing process chains; - microsystems and microengineering technologies; - specificities in the field of micro-manufacturing; - products and market; - microfluidic systems. <p>2. Chemical principles of material deposition and removal:</p> <ul style="list-style-type: none"> - examples in the field of microsystems and microengineering technologies; - microsystem technologies: materials, mono- and polycrystals, some procedures of dry and wet etching, choice of appropriate procedure, product examples. <p>3. Microsystem technologies (continuation):</p> <ul style="list-style-type: none"> - bulk micromachining; - surface micromachining; - LIGA procedure; laser direct imaging; CAD-CAM, machining parameters, photopolymers and etchants; - product examples. <p>4. Microelectrochemical etching:</p> <ul style="list-style-type: none"> - mechanism of anodic dissolution, basic equation of material removal; - process control; - machining characteristics;
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<ul style="list-style-type: none"> - primeri izdelkov; - stroji - koncepti in pregled trga; - trendi razvoja. <p>5. Mikroelektroerozijska obdelava:</p> <ul style="list-style-type: none"> - posebnosti žične in potopne mikroelektroerozije; - mikroelektroerozijsko dolbenje: kinematika, kompenzacija obrabe elektrode; - primeri izdelkov in značilnosti obdelave; - stroji: koncepti in pregled trga; - trendi razvoja. <p>6. Mikrolaserska obdelava:</p> <ul style="list-style-type: none"> - sublimacijsko, oksidacijsko in talilno odnašanje materiala; - vloga rezalnih plinov; - pomen frekvenca laserskih pulzov; - lasersko dolbenje; - varjenje polimerov; - vrtanje lukenj; - primeri izdelkov in značilnosti obdelave. <p>7. Mikromehanska obdelava:</p> <ul style="list-style-type: none"> - izdelava orodij za mikromehansko obdelavo; - mikromehansko dolbenje: kinematika, obdelovalni parametri, nadzor procesa, »fly cutting«; - diamantno struženje: stroji, orodja; - obdelava krhkih materialov; - mikropeskanje: koncepti naprav, šobe, maske; - primeri izdelkov in značilnosti obdelave; - trendi razvoja. <p>8. Aditivne tehnologije:</p> <ul style="list-style-type: none"> - postopki primerni za mikroizdelke; - mehanizmi spajanja materiala; - stroji: koncepti in pregled trga; - trendi razvoja. <p>9. Stereolitografija za mikroizdelavo:</p> <ul style="list-style-type: none"> - laserska stereolitografija; - kontinuirana stereolitografija (CLIP); - dvofotonska litografija; - fotopolimeri; - stroji: koncepti in pregled trga; - trendi razvoja. <p>10. Stereolitografija s projiciranjem maske za mikroizdelavo:</p> <ul style="list-style-type: none"> - pristopi k gradnji izdelka; 	<ul style="list-style-type: none"> - product examples; - machine tools: concepts and market overview; - development trends. <p>5. Micro EDM:</p> <ul style="list-style-type: none"> - specificities of wire and die-sinking micro EDM; - micro EDM milling: kinematics, electrode wear compensation; - product examples and machining characteristics; - machine tools: concepts and market overview; - development trends. <p>6. Laser micromachining:</p> <ul style="list-style-type: none"> - sublimation, oxidation and melting material removal processes; - the role of cutting gases; - importance of laser pulse frequency; - laser engraving; - welding of polymers; - drilling holes; - product examples and machining characteristics. <p>7. Mechanical micromachining:</p> <ul style="list-style-type: none"> - manufacturing of tools for mechanical micromachining; - micromilling: kinematics, machining parameters, process control, fly cutting; - diamond turning: concepts, tools; - treatment of brittle materials; - micro sand blasting: machine tools, nozzles, masks; - product examples and processing characteristics; - development trends. <p>8. Additive manufacturing technologies:</p> <ul style="list-style-type: none"> - processes suitable for micro-products; - material joining mechanisms; - machine tools: concepts and market overview; - development trends. <p>9. Stereolithography for micro products:</p> <ul style="list-style-type: none"> - laser stereolithography; - continuous stereolithography (CLIP); - two-photon lithography; - photopolymers; - machine tools: concepts and market
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<ul style="list-style-type: none"> - optični sistemi; - model fotopolimerizacije; - primeri izdelkov. <p>11. Mikrobrizganje:</p> <ul style="list-style-type: none"> - brizgalna enota za mikrobrizganje; - cikel brizganja; - orodja; - materiali in podatkovne baze; - gradnja modela in simuliranje brizganja. <p>12. Mikrobrizganje:</p> <ul style="list-style-type: none"> - nadzor, analiza procesa in odprava napak; - parametri izdelave in značilnosti postopka; - stroji: pregled trga, brizganje na »makro« brizgalnih strojih; - trendi razvoja. <p>13. Vroče vtiskovanje:</p> <ul style="list-style-type: none"> - osnovni proces in izpeljanke, materiali in termično okno; - orodja; - značilnosti obdelave; - primeri izdelkov; - stroji: koncepti in pregled trga; - trendi razvoja. <p>14. Izdelovalne verige:</p> <ul style="list-style-type: none"> - direktne in indirektne izdelovalne verige; - postavitev ustrezne izdelovalne verige glede na velikost serije, natančnosti izdelave, pogoje v katerih deluje mikroizdelek; - "mehka" orodja; primeri iz prakse. <p>15. Mikroreaktorski sistemi:</p> <ul style="list-style-type: none"> - koncept mikroreaktorja: mešalnik, reaktor, separator; - reakcijski čas in čas zadrževanja; - problem majhne produktivnosti: večanje dimenzij in večanje številčnosti; - koncept mikrotovarne. 	<p>overview;</p> <ul style="list-style-type: none"> - development trends. <p>10. Mask projection stereolithography:</p> <ul style="list-style-type: none"> - concepts of product design; - optical systems; - photopolymerization model; - product examples. <p>11. Micro injection moulding:</p> <ul style="list-style-type: none"> - micro injection molding unit; - injection cycle; - tools; - materials and databases; - model and simulation of injection molding. <p>12. Micro injection moulding:</p> <ul style="list-style-type: none"> - monitoring , process analysis and error correction; - machining parameters and characteristics; - machines tools: market overview, injection molding on "macro" injection molding machines; - development trends. <p>13. Hot embossing:</p> <ul style="list-style-type: none"> - basic process and derivatives, materials and thermal window; - tools; - machining parameters and characteristics; - product examples; - machine tools: concepts and market overview; - development trends. <p>14. Process chains:</p> <ul style="list-style-type: none"> - direct and indirect process chains; - setup of a process chain based on the batch size, required accuracy, operation conditions of micro-product; - soft tooling; practical examples. <p>15. Microreactor systems:</p> <ul style="list-style-type: none"> - concept of microreactor: mixer, reactor, separator; - reaction time and residence time; - the problem of low productivity: scaling up and numbering up concepts; - micro-factory concept.
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Temeljna literatura in viri/Readings:

1. M. Madou: Fundamentals of Microfabrication and Nanotechnology, 3rd edition,

CRC Press, 2012 [COBISS.SI-ID [13981238](#)]

2. Yi Qin: Micromanufacturing Engineering and Technology, William Andrew Publishing, 2010. E-knjiga ISBN - 0-8155-1545-6; 0-8155-1980-X; 9786612711763; 1-282-71176-8; 0-08-094740-9
3. V.K. Jain: Introduction to Micromachining, Alpha Science, 2010. [COBISS.SI-ID [33734917](#)]
4. G. Tosselo: Micro injection molding, Carl Hanser Verlag GmbH & Co. KG, 2019. [COBISS.SI-ID [146819075](#)]
5. Gibson, Ian idr.: Additive manufacturing technologies : 3D printing, rapid prototyping and direct digital manufacturing, New York : Springer, 2015. [COBISS.SI-ID [13909019](#)]

Cilji in kompetence:

Cilji:

1. Spoznati mikroizdelovalne tehnologije z vidika fizikalnih procesov in njihovih tehnoloških zmogljivosti.
2. Spoznati uporabo/vlogo mikrotehnologij v sodobnih proizvodnih procesih.
3. Pridobljeno znanje iz literature uporabiti v praksi in predstaviti rezultate.
4. Določiti primerne tehnologije oz. izdelovalne verige za mikroizdelke.
5. Gradnja numeričnih modelov za izvajanje simulacij nekaterih mikroizdelovalnih procesov in za načrtovanje mikrokomponent.

Kompetence:

1. S2-MAG, P2-MAG, P3-MAG: Obvladovanje mikroizdelovalnih tehnologij in področji njihove uporabe.
2. S1-MAG, S7-MAG, P1-MAG, P2-MAG: Sposobnost iskanja tehnoloških rešitev za izdelavo mikroizdelkov.
3. S5-MAG, S8-MAG, P5-MAG: Sposobnost iskanja virov informacij, kritične presoje in praktične uporabe.
4. S1-MAG, S7-MAG, P1-MAG, P2-MAG: Sposobnost načrtovanja izdelkov, ki jih je mogoče učinkovito izdelati z mikroizdelovalnimi tehnologijami.

Objectives and competences:

Objectives:

1. To get familiar with micromanufacturing technologies in terms of physical processes and their technological capabilities.
2. To understand the use/role of microtechnologies in modern production processes.
3. Apply the knowledge from the literature to practice and present the results.
4. Identify appropriate technologies and/or process chains for micro product manufacturing.
5. Building of numerical models and performing simulations of some micro-manufacturing processes and for design of micro-components.

Competences:

1. S2-MAG, P2-MAG, P3-MAG: Mastering micro-manufacturing technologies and applications.
2. S1-MAG, S7-MAG, P1-MAG, P2-MAG: Ability to find technological solutions for micro-product manufacturing.
3. S5-MAG, S8-MAG, P5-MAG: Ability to search for sources of information, critical judgment and practical application.
4. S1-MAG, S7-MAG, P1-MAG, P2-MAG: The ability to design products that can be effectively fabricated with micromanufacturing technologies.

5. S6-MAG + P4-MAG: Sposobnost izvajanja simulacij nekaterih mikroizdelovalnih procesov in uporabe mikrokomponent.	5. S6-MAG + P4-MAG: Ability to perform simulations of some micromanufacturing processes and use of microcomponents.
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Predvideni študijski rezultati:

<p>Znanja:</p> <p>Z2: Poglobljeno teoretično, metodološko in analitično znanje z elementi raziskovanja, ki je osnova za zelo zahtevno strokovno delo.</p> <p>Spretnosti:</p> <p>S2.1 Obvladovanje zelo zahtevnih, kompleksnih delovnih procesov in metodoloških orodij na specializiranih področjih.</p> <p>S2.3 Sposobnost izvirnih dognanj/stvaritev in kritične refleksije.</p>	<p>Intended learning outcomes:</p> <p>Knowledge:</p> <p>Z2: Thorough theoretical, methodological and analytical knowledge with elements of a research work that form a basis for very demanding professional work</p> <p>Skills:</p> <p>S2.1 Mastering very demanding and complex work processes and methodological tools in specialised professional fields.</p> <p>S2.3 Ability of unique innovations and critical reflections.</p>
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Metode poučevanja in učenja:

<p>P1 Avditorna predavanja z reševanjem izbranih - za področje značilnih - teoretičnih in praktično uporabnih primerov.</p> <p>P2 Obravnava snovi po urejeni in vnaprej razloženi sistematiki.</p> <p>P3 Avditorne vaje, kjer se teoretično znanje s predavanj podkrepi z računskimi primeri.</p> <p>P6 Interaktivna predavanja</p> <p>P7 Študij literature in razprava</p> <p>P8 Izdelava in predstavitev aplikativnih seminarskih nalog</p> <p>P10 Uporaba anket v realnem času</p> <p>P15 Uporaba video vsebin kot priprava na predavanja in vaje</p>	<p>Learning and teaching methods:</p> <p>P1 Auditorial lectures with solving selected field-specific theoretical and applied use cases.</p> <p>P2 Presenting the content according to the explained system.</p> <p>P3 Auditorial exercises, in which theoretical content from the lectures is supplemented with practical examples.</p> <p>P6 Interactive Lectures</p> <p>P6 Interactive lectures.</p> <p>P7 Literature study and discussion.</p> <p>P8 Making and presenting applied seminar exercises.</p> <p>P10 Application of questionnaires in real time.</p> <p>P15 Application of videos for preparations to the lectures and exercises.</p>
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Načini ocenjevanja:

Delež/ Weight

Assessment:

- Teoretične vsebine (predavanja).	50,00 %	- Theoretical content (lectures).
- Delo na laboratorijskih vajah (vključno s poročili).	20,00 %	- Laboratory work (including reports).
- Seminar.	30,00 %	- Seminar.

Ocenjevalna lestvica:
Grading system:

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Reference nosilca/Lecturer's references:
Joško Valentinčič:

1. **VALENTINČIČ, Joško**, GLOJEK, Andrej, SABOTIN, Izidor. Design, simulation, and injection moulding of a microreactor baseplate. Journal of micro- and nano-manufacturing, ISSN 2166-0468. [Print ed.], Sep. 2016, vol. 4, nr. 3, str. 1-6. [COBISS.SI-ID [14979867](#)]
2. KITANOVSKI, Andrej, TOMC, Urban, KLINAR, Katja, **VALENTINČIČ, Joško**, MAJDIČ, Franc, SABOTIN, Izidor, MENCINGER, Jure. Method for heat transfer in the embedded structure of a heat regenerator and the design thereof : patent CN 112654778 B, 2023-08-15. Beijing: China National Intellectual Property Administration (CNIPA), 2023. [COBISS.SI-ID [14214659](#)]
3. BISSACCO, Giuliano, TRISTO, Gianluca, HANSEN, H. N., **VALENTINČIČ, Joško**. Reliability of electrode wear compensation based on material removal per discharge in micro EDM milling. CIRP annals, ISSN 0007-8506, 2013, vol. 62, iss. 1, str. 179-182. [COBISS.SI-ID [13237531](#)]
4. SABOTIN, Izidor, JERMAN, Marko, LEBAR, Andrej, **VALENTINČIČ, Joško**, BÖTTGER, Toni, KÜHNEL, Lisa, ZEIDLER, Henning. Effects of plasma electrolytic polishing on SLM printed microfluidic platform. Advanced technologies and materials, ISSN 2620-0325, 2022, vol. 47, nr. 1, str. 19-23. [COBISS.SI-ID [132569603](#)]
5. ŠADL, Matej, PRAH, Uroš, KOVACOVA, Veronika, DEFAY, Emmanuel, ROJAC, Tadej, LEBAR, Andrej, **VALENTINČIČ, Joško**, URŠIČ NEMEVŠEK, Hana. Multifunctional flexible ferroelectric thick-film structures with energy storage, piezoelectric and electrocaloric performance. Journal of materials chemistry. C, Materials for optical and electronic devices, ISSN 2050-7534. [Online ed.], 2023, 11, str. 10058-10068 [COBISS.SI-ID [160044035](#)].