Undergraduate study programmes

Course: General Chemistry		
Language: Croatian		
Lecturer: Dr. Svjetlana Krištafor, Assistant Professor; Dr. Ivana Steinberg, Assistant Professor		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**2**	**30**
Seminar	**2**	**30**
		Overall: 90
		ECTS: 8

PURPOSE: To gain a basic knowledge in general chemistry and chemical calculation; to introduce students to the world of chemistry emphasizing the structure of matter; acquiring basic laboratory skills; to be able to apply knowledge gained in this course in more advanced courses and throughout ones career.

THE CONTENTS OF THE COURSE:

1st week: Introduction to the course; the importance of chemistry and chemical principles; definitions – chemistry today; atom – an overview of discoveries;

2nd week: The discovery of electron and nucleus; introduction to quantum mechanics; the characteristics of electromagnetic radiation – atomic spectra; quantum theory.

3rd week: Quantum theory and atomic structure; atomic orbitals and energy levels; electronic structure and periodic table.

4th week: Chemical bonds – ionic and covalent bonds; Lewis structures; Resonance.

5th week: Ionic character of covalent bond; intermolecular forces; formal charge; metallic bond; molecular structure and shape; molecular orbital theory; electron configurations and bond order of diatomic molecules

6th week: Valence bond theory and hybridization; geometry of molecule; multiple bonds; coordination compounds.

7th week: The properties of gases; the gas laws; applications of ideal gas law; the kinetic model of gases; real gases; liquids and solids – structure.

8th week: Thermochemistry; enthalpy and entropy; Gibbs free energy; physical equilibria; phase transitions.

9th week: Chemical equilibria; acids and bases

10th week: Aqueous equilibria; buffers; titrations; solubility equilibria

11th week: Electrochemistry – oxidation/reduction equations; electrochemical cells;

12th week: Coordination compounds; the electronic structure of complexes; spectrochemical series; the colours of complexes

13th week: Chemical kinetics; reaction rates and mechanisms; Nuclear chemistry

14th week: Selected topics on application of chemical principles

15th week: Selected topics on application of chemical principles; Revision and the summary of the course

GENERAL AND SPECIFIC COMPETENCE:

The main objective of this course is to give students a basic foundation in chemistry, including development of skills required for problem solving and the application of basic chemical concepts. Students will learn to think at the atomic structural level of matter and to relate the electronic structure of atoms to the chemical properties of elements. The understanding of how atoms combine with one another and its importance in relation to the research in pharmaceuticals, agricultural chemicals, polymers and synthetic materials. After completion of this course, students will be able to use the periodic table and understand the symbolism and language of chemistry. After the successful completion of the laboratory part of this course, students will have acquired the skills necessary for scientific work – critical thinking and observation skills, ability to safely handle chemical reagents.

KNOWLEDGE TESTING AND EVALUATION:

Three written tests during the semester

Written and oral examinations

Exam related to laboratory practice (successful completion of laboratory practice is needed for completion of the course)

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student survey

LITERATURE:

1. I. Filipović, S. Lipanović: "*Opća i anorganska kemija*", Školska knjiga, Zagreb, 1991.
2. M. Sikirica: "*Stehiometrija*", Školska knjiga, Zagreb, 1991.
3. P. Atkins, L. Jones: "*Chemical Principles: The Quest for Insight*", 4th ed. New York, NY: W.H. Freeman and Company, 2007.

Course: Mechanics of Materials		
Language: English		
Lecturer: Domagoj Vrsaljko		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**0**	**0**
Seminar	**1**	**15**
		Overall: 45
		ECTS: 4.0

PURPOSE:

Acquiring general technical knowledge and fundamentals of the mechanical behaviour of materials. The acquired knowledge will be useful to them during their studies on senior years, as well as for future applications in engineering practice.

THE CONTENTS OF THE COURSE:

Week 1

Introduction to engineering graphics. Technical standards.

Week 2

Fundamentals of engineering mechanics. Statics. Force, torque.

Week 3

Creating a free-body diagram.

Week 4

Friction. Belt Friction.

Week 5

Friction of pulleys.

Week 6

1st partial written exam: statics, friction.

Week 7

Mechanics of deformable bodies - Fundamentals and applications. Stress and strain.

Week 8

Constitutive equation. Mechanical properties of materials: static strength. Strength Theories. Elasticity, plasticity, viscoelasticity.

Week 9

Exercise: The mechanical properties of materials: static strength (universal testing machine).

Week 10

Main applied loads: tensile, compressive. Generalized Hooke's law. Sizing construction elements, numerical methods. True and calculated stress. Diagram of strain, Poisson number, modulus of elasticity.

Week 11

Thermal stress.

Week 12

Torsion, bending, shear, buckling.

Week 13

2nd partial written exam: Constitutive equation.

Week 14

Mechanical properties of materials: creep, relaxation, impact toughness, hardness. Fracture mechanics.

Exercise: Mechanical Properties of Materials: Impact toughness.

Week 15

Mechanical properties of materials: creep and fatigue. Methods of material processing. Examples of applications of mechanics of materials.

Exercise: The mechanical properties of the material: hardness.

GENERAL AND SPECIFIC COMPETENCE:

Mastering the fundamentals of the mechanical behaviour of engineering materials and dimensioning of elements. Adopting an integrated approach to solving of problems.

KNOWLEDGE TESTING AND EVALUATION:

2 partial written exams during the course, or 1 written exam at the end of course.

Oral exam (after passing the written part of the exam).

Final mark is derived from the success during the written and oral exams and exercises.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student survey.

LITERATURE:

I. Alfirević, J. Saucha., Z. Tonković, J. Kodvanj: Uvod u mehaniku 1, Statika krutih tijela, Golden marketing-Tehnička knjiga, Zagreb, 2010.

I. Alfirević, Nauka o čvrstoći I, Tehnička knjiga, Zagreb, 1995.

M. Franz, Mehanička svojstva materijala, FSB, Zagreb, 1998.

http://www.fkit.unizg.hr/predmet/mehmat/mehanika_materijala

Krautov strojarski priručnik, Sajema d.o.o. Zageb, 2009.

I. Alfirević i B. Modlic, Inženjerski priručnik - Temelji inženjerskih znanja, Školska knjiga, Zagreb, 1996.

F.P. Beer, E.R. Johnston and J.T. DeWolf, Mechanics of Materials, McGraw Hill, New York 2005.

Course: INORGANIC CHEMISTRY (CEM)		
Language: Croatian		
Lecturer: : Dr. sc. Stjepan Milardovic, associate professor		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**3**	**24**
Seminar	**0**	**0**
		Overall: 54
		ECTS: 5

PURPOSE:

Introducing students with properties of chemical elements and chemical compounds using the information about ionization energy, electron affinity, electronegativity, standard-state reduction potentials, atomic radii, etc. Introducing with the periodic trends in the chemical and physical properties of the elements Introducing to some aspect of bioinorganic chemistry, organometallic chemistry, and theoretical model of chemical structures and with industrial and analytical aspect of inorganic chemistry.

THE CONTENTS OF THE COURSE:

1. The low of chemical periodicity and periodic table. Periodic trends in physical and chemical properties along the periods and along the groups. Periodicity of chemical properties (electronegativity, ionization energy, electron affinity, oxidation numbers, standard-state reduction potential), periodic trends in physical properties (melting point, boiling points, etc.)

2. Hydrogen

The general atomic and physical properties of molecular hydrogen, preparation in industrial and laboratory scale. Ionized form of hydrogen (ionic hydrides, covalent hydrides, polymeric and intermediate hydrides). The hydrogen bond and hydrogen isotopes.

3.The elements of 18th group (noble gases)

Atomic and physical properties of the elements. Preparation production and use.

Compounds of xenon and compounds of other noble gases

4.The elements of 17^{th} group (the halogens)

The general chemical properties of the halogens group of elements, physical and chemical trends along the group, the change of electronegativity along the group, properties of compound concerning oxidation numbers in the range :-1, 0, +1, +3, +4, +5, +7. Chemical reactivity of diatomic halogens, preparation and properties of hydrogen halides. Psudohalogens, preparation and properties. Oxoacid and oxoacid salts (preparation and properties).

5. The elements of 16^{th} group (chalcogens)

The general chemical properties of the chalcogens group of the elements. The properties of compounds concerning oxidation numbers in the range –2, –1, 0, +2, +3, +4,+6. Chemical properties and preparation of dioxygen (O2) ozone (O3) and atomic oxygen (O). The properties of oxygen compounds concerning negative oxidation state (O^{2-}), (O_2^{2-}),(O_2^-), (O_3^-) and positive oxidation state (O_2^+). Physical properties and structure of water, oxoacids of sulphur, selenium and tellurium, thioacids. Redox properties along the group.

6. The elements of 15^{th} group (nitrogen group of the elements)

The general chemical properties of the nitrogen group of the elements. The change of electronegativity along the group, properties of compounds concerning oxidation states in the range –3, -1, 0, +1, +3, +5. Preparation and chemical properties of ammonia and ammonium salts, nitric acid, hydrazine, nitrogen oxides (N_2O, NO, NO_2, N_2O_3, N_2O_5) and oxoacid of nitrogen. Preparation, use and chemical properties of hydrides of nitrogen, phosphorus, arsenic, antimony and bismuth.

7. The 14^{th} group of the elements (carbon group)

The general chemical properties of the carbon group of the elements. Preparation, physical and chemical properties of carbon (diamond, graphite, fullerene, graphene) CO and CO_2.

Chemical properties of the carbon (negative oxidation state) compounds (carbides) and silicon (silicides). Chemical properties, preparation and use of silicates and silicon. Chemical and physical properties of germanium tin and lead compounds of positive oxidation state (+2, +4). Lead battery.

8. The 13^{th} group of the elements (boron group)

The general chemical properties of the boron group of the elements. Properties of compounds concerning oxidation states in the range –3, -1, 0, +1, +2, +3. Preparation, use and chemical properties of ortoboric acid. Preparation, use and chemical properties of aluminium, aluminium trihalides, amphoteric properties of aluminium and aluminium passivity. Chemical properties of indium and gallium compounds.

9.The 2^{nd} group of the elements (alkaline earth metals)

Chemical reactivity and trends of chemical and physical properties along the group. Introduction to hydrides, oxides, oxoacides, hydroxides and organometallic compounds.

10. The 1^{st} group of the elements (alkali metals)

Chemical reactivity and trends of chemical and physical properties along the group. Introduction to hydrides, peroxides, superoxide's, hydroxides and organometallic compounds. Preparation of NaOH, $NaHCO_3$, NaCl and gypsum.

11. Preparation and properties of metals

12.

Chemical reactivity and trends of chemical and physical properties along the group of the lanthanides and actinides. The general properties of the elements of the 4^{th} and 5^{th} group of the elements, oxides, sulphides, oxoanions and complexes of titanium, zirconium and hafnium.

13.

Chemical reactivity and trends of chemical and physical properties along the d-group of elements (vanadium, chromium and manganese). Oxides and the most important compounds (oxidation states 2, 3, 4, 5 and 6).

14.

Chemical reactivity and trends of chemical and physical properties along the d-group of elements (iron, cobalt and nickel) and 8^{th}, 9^{th} and 10^{th} group of elements. Oxides, oxyanions, complexes.

15.

Chemical reactivity and trends of chemical and physical properties along the d-group of copper and zinc (11^{th} and 12^{th} group of elements). Oxides, oxyanions, complexes, biochemistry of copper.

Laboratory practice

Experiments 1 day

- Hydrogen production by reaction of aluminium and sodium hydroxide
- Iodine preparation by iodate reduction
- Preparation and properties of oxygen
- The properties of metal oxides and hydroxides
- Preparation of sodium thiosulphate

Experiments 2 day

- Preparation of silver thiosulphate and its reactivity
- Preparation and properties of nitrogen
- Preparation of ammonia
- Preparation of sodium carbonate

Experiments 3 day

- Preparation of the lead(IV) oxide. Lead-Acid Battery
- Preparation of lead(II) chloride
- Preparation of boric acid

Experiment 4 day

- Preparation of potassium aluminium sulphate dodecahydrate
- Preparation of copper(II) oxide
- Preparation of copper(I) chloride
- Preparation of tetraaminecopper(II) sulphate monohydrate

Experiments 5 day

- Preparation of sodium chromate
- Preparation of chromium(III) oxide
- Preparation of potassium chromium alum
- Precipitation and properties of manganese(II) hydroxide

- Preparation of potassium manganite and permanganate

Experiments 6 day

- The reduction by vanadium salts in Joneses reductor
- Preparation of iron(II)sulphate pentahydrate
- Precipitation and properties of iron(III) hydroxide
- Preparation of potassium hexacyanoferrate(III)

Experiments 7 day

- Preparation of Mohr’s salt
- Complexes of cobalt
- Preparation of mercury(I) iodide
- Preparation of mercury(II) oxide

Experiment 8 day

- Titration of a phosphoric acid solution with sodium hydroxide
- Titration of silver nitrate solution with potassium iodide

GENERAL AND SPECIFIC COMPETENCE:

The main general competence is to understand the basic of inorganic chemistry and adequate application of low of periodicity to predict the properties of elements or compounds. Using the modern theory of bonding to predict the structure, reactivity, acid-base properties and redox properties of elements and compounds.

KNOWLEDGE TESTING AND EVALUATION:

Write exam and oral exam

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Continuous evaluation.

LITERATURE:

1. I. Filipović i S. Lipanović: “ Opća i anorganska kemija”, Školska knjiga, Zagreb, 1991.

2. N. N. Greenwood, A. Earnshaw: “ Chemistry of the Elements”, Pergamon Press, Oxford, 2002.

3. D. F.Shriver and P.W. Atkins; Inorganic Chemistry”, Oxford University Press, third edition, 1999.

Course: Organic Chemistry I		
Language: English		
Lecturer: Prof. Silvana Raić-Malić, Ph.D.		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**3**	**45**
Laboratory	**2**	**30**
Seminar	**0**	**0**
		Overall: 75
		ECTS: 7

PURPOSE:

The main objective of the course is to familiarize students with the basic principles of modern organic chemistry, understanding the structure-activity relationship of organic compounds and application of methods in the synthesis of organic compounds in biosciences and industry.

THE CONTENTS OF THE COURSE:

1. CARBON COMPOUNDS AND INTRODUCTION TO STRUCTURAL THEORY OF ORGANIC CHEMISTRY: introduction to structural theory: the empirical and structural molecular formulas, isomers, tetrahedral structure of methane; chemical bonds - the octet rule, ionic and covalent bonds, Lewis structures, resonance; quantum mechanics, atomic and molecular orbitals; structure of methane and ethane: sp^3-hybiridization; structure of ethene: sp^2-hybiridization, *cis-trans*-isomerism; structure of ethyne: sp-hybridization.
2. INTRODUCTION TO ORGANIC REACTIONS: ACIDS AND BASES: Types of chemical reactions and their mechanisms; acid-base reactions, Brönsted, Lowry and Lewis definitions of acids and bases; heterolysis of carbon bond (carbocations and carbanions), the strength of acids and bases, the relationship between structure and function of acid, the acidity of carboxylic acids, organic compounds as bases; introduction to the mechanisms of organic reactions.
3. CLASSES OF CARBON COMPOUNDS, FUNCTIONAL GROUPS: Hydrocarbons: alkanes, alkenes, alkynes and aromatic compounds; functional groups in organic molecules, alkyl halides, alcohols, ethers, amines, aldehydes and ketones, carboxylic acids, esters, amides, nitriles. The relationship of the structure and physical properties of the molecules (hydrogen bonding, van der Waals forces).
4. ALKANES – CONFORMATIONAL ANALYSIS AND INTRODUCTION TO SYNTHESIS: Conformational analysis of alkanes, relative stability of cycloalkanes - ring tension, *cis*- and *trans*-isomerism of cycloalkanes, syntheses of alkanes and cycloalkanes.
5. STEREOCHEMISTRY AND CHIRALITY I: The biological significance of chirality; isomerism: constitutional isomers and stereoisomers; chiral

molecules and enantiomers, enantiomer nomenclature (Cahn-Ingold-Prelog system of rules *R*, *S*), relative and absolute configuration, optical activity of enantiomers, molecules with multiple chiral centers, *meso*-compounds, Fischer projection formula, stereoisomerism of cyclic compounds.

6. STEREOCHEMISTRY AND CHIRALITY II: Heteroatoms as centers of chirality, axial chirality, helical structure, homochirality in nature, pseudochirality, prochirality, diastereomers, preparation of enantiomerically pure compounds (fractional crystallization of racemates, chromatographic separation of enantiomers on chiral stationary phases), chiral drugs interactions of drug enantiomer and receptor.

7. IONIC REACTIONS - NUCLEOPHILIC SUBSTITUTION REACTIONS OF ALKYL HALIDE: Nucleophilic substitution reactions: nucleophiles, leaving groups; kinetics, mechanism and stereochemistry of S_N1 and S_N2 reactions (carbocations); examples of organic synthesis by functional group transformation in S_N2 reactions.

8. IONIC REACTIONS - ELIMINATION REACTIONS OF ALKYL HALIDE: The impact of nucleophile on the elimination and substitution competitive reactions; mechanism of E1 and E2, stereoselectivity and regioselectivity of reaction E1, stereospecifity of substituted cyclohexane in E2 reactions, regioselectivity in elimination reactions (Hoffman's and Zaitsev's rule), carbanionic mechanism of elimination (E1cB).

9. ALKENES AND ALKYNES I: SYNTHESIS AND PROPERTIES: Determining of *E*-and *Z*-configuration, the relative stability of alkenes, cycloalkenes, synthesis of alkenes by dehydrohalogenation of alkyl halide and dehydration of alcohols, and stability of carbocation and molecular rearrangement, synthesis of alkynes in elimination reactions, acidity of terminal alkynes.

10. ALKENES AND ALKYNES II: THE ADDITION REACTION: Hydrogen halides addition to alkenes (Markovnikov's rule), the stereochemistry of ionic addition reaction of alkenes, oxymercuration and demercuration of alkenes (Markovnikov's additions) synthesis of alcohol by hydroboration and oxidation of alkenes (*syn*-hydration, anti-Markovnikov's rule), hydroboration of alkenes and synthesis of alkyl-borane, halogen addition to alkenes, the stereochemistry of the addition reaction of halogen to alkenes.

11. STRUCTURE DETERMINATION OF ORGANIC COMPOUNDS BY NUCLEAR MAGNETIC RESONANCE AND MASS SPECTROMETRY: Introduction to nuclear magnetic resonance spectroscopy (NMR), the spin of protons, shielding and deshielding effects of protons, chemical shift, chemical equivalent and non-equivalent protons, splitting of signal: the spin-spin coupling, ^1H and ^{13}C one- and two-dimensional nuclear magnetic resonance spectroscopy (1D and 2D NMR), introduction to mass spectrometry, ionization and fragmentation of molecular ion, determination of molecular formula and mass, applications of mass spectrometry in biomedicine.

12. RADICAL REACTIONS: Energy of homolytic bond cleavage and relative stability of radicals, selectivity in radical substitution reactions, chlorination of methane - energy activation, halogenation of higher alkanes, the geometry of alkyl radicals, radical additions to alkenes (anti-Markovnikov's addition of hydrogen halide), radical polymerization of alkenes, radicals in biology, medicine and industry.

13. ALCOHOLS: Synthesis of alcohols from alkenes, reactions of alcohols, alcohols as acids, conversion of alcohols to alkyl halides, the reaction mechanism of alcohols with hydrogen halides, alcohol derivatives with leaving groups: tosylates, mesylates and triflates, the reaction of alcohols with aldehydes and ketones – preparation of hemiacetals and acetals, silyl ethers as protecting groups of alcohols, sugar alcohols.

14. ETHERS: synthesis of ethers, silyl protecting groups of ethers, reactions of ethers (cleavage of ethers by strong acids), cyclic ethers (epoxides): synthesis by epoxidation of alkenes, Sharpless asymmetric epoxidation of alkenes; reaction of epoxides (acid-catalyzed ring-opening reaction, crown ethers: phase-transfer catalysts.

GENERAL AND SPECIFIC COMPETENCE:

The main goal of student education is to acquire the principles of organic chemistry and methods of organic synthesis, and their application in the synthesis of new compounds.

Specific competences: to acquire the basic techniques in the synthesis of organic compounds and their identification.

KNOWLEDGE TESTING AND EVALUATION:

Continuous monitoring of knowledge and evaluation of student work through homeworks (6) and tests (3) during the semester.

Written and oral exams.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student survey.

LITERATURE:

1. T. W. G.Solomon, C. B. Fryhle, Organic Chemistry, J. Wiley, 2004.
2. J. Clayden, N. Greeves, S. Warren, P. Wothers, Organic Chemistry, Oxford University Press, Oxford, 2001.
3. S. Pine, Organic chemistry, written in Croatian, translated by: I. Bregovec, V. Rapić, Školska kniga, Zagreb, 1994.
4. K. Peter, C. Vollhardt, N. E. Shore, Organic Chemistry: Structure and function, W. H. Freeman and Company, 5th Ed., 2007.
5. L. G. Wade Jr., Organic Chemisty, Pearson Prentice Hall, London, 2006.
6. V. Rapić, The nomenclature of organic compounds, written in Croatian, Školska knjiga, 3rd revised and supplemented Ed., Zagreb, 2004.

Course: Physical Chemistry I		
Language:		
Lecturer: Marica Ivanković ; Jelena Macan		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**3**	**45**
Laboratory	**2**	**30**
Seminar	**0**	**0**
		Overall: 75
		ECTS: 6

PURPOSE:

Understanding of basic laws and theories of physical chemistry as applied in practice of chemical engineering. Development of capabilities of logical problem solving and equation derivation.

THE CONTENTS OF THE COURSE:

1. week: Introduction, phase states of matter, ideal gas – equation of state
2. week: Kinetic-molecular theory of gasses, velocity and energy of gas molecules, Maxwell-Boltzmann distribution
3. week: Real gasses – equation of state, liquefaction
4. week: First partial exam
5. week: Thermodynamics: heat and work, The first law, internal energy, enthalpy, heat capacities
6. week: Thermochemistry: Hess's law, Kirchhoff's law, adiabatic processes
7. week: Spontaneous processes and equilibrium, Carnot cycle, The second law of thermodynamics, reversibility of processes
8. week: Gibbs free energy, The third law of thermodynamics, dependence of Gibbs energy on temperature and pressure, fugacity
9. week: Second partial exam
10. week: deal and non-ideal mixtures, chemical potential, Gibbs-Duhem equation
11. week: Phase equilibria, Clapeyron and Clausius-Clapeyron equation, triple point, phase rule
12. week: Raoult's law, colligative properties of mixtures, Henry's law
13. week: Distillation, vapour pressure diagrams, boiling diagrams
14. week: Basics of phase equilibria of three-component systems, distribution law, crystallization, osmotic equilibrium
15. week: Third partial exam

Laboratory work:
1. Determination of molecular mass by V. Meyer's method
2. Calorimetry – determination of heat of reaction
3. Cryoscopy
4. Boiling diagram
5. Nernst distribution law

GENERAL AND SPECIFIC COMPETENCE:

Describing the basic physical chemistry laws regarding gasses, thermodynamics and phase equilibria.
Applying knowledge of mathematics and deriving the equations (clearly describing the physical

phenomena under consideration).
Preparing and performing laboratory experiments.
Analysis and interpretation of experimental results.
Preparation of laboratory reports.

KNOWLEDGE TESTING AND EVALUATION:

Exams, partial exams, entrance and final colloquium in laboratory work.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student opinion surveys

LITERATURE:

P. Atkins, J. de Paula, Atkin's Physical Chemistry, 8th edition, Oxford University Press, Oxford 2006.

Course: Mass ana energy balance		
Language: English		
Lecturer: Associate prof. Ana Vrsalović Presečki, PhD		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory		
Seminar	**2**	**30**
		Overall: 60
		ECTS: 5

PURPOSE: Introduce students to the application of the law of conservation of mass and energy in chemical processes; teach them the basics of chemical engineering process analysis and computation mass and energy balances of steady-state and unsteady-state processes.

THE CONTENTS OF THE COURSE:

1st week

The fundamental laws, concepts and techniques in chemical engineering analysis.

2nd week

Processes and process variables. Mass balances (general equation, differential and integral balance).

3rd week

Mass balance of the steady-state processes. Mass balances of the unsteady-state processes. Computation based on balances of steady-state processes (systems of linear equations).

4th week

Mass balance of the physical process, non reacting process in a single process unit.

5th week

Mass balance of the process with single chemical reaction in a single process unit.

6th week

Mass balance of the process with multiple chemical reactions in a single process unit.

7th week

Mass balance of combustion process

8^{th} week

Mass balance of physical processes performed in the multiple unit processes.

9^{th} week

Energy and chemical engineering. Fundamental concepts in energy balance. The general equation of the energy balance.

10^{th} week

Energy balance of the closed system. Energy balance of open systems (steady state process).

11^{th} week

Computation in chemical engineering based on energy balance of single component process.

12^{th} week

Computation in chemical engineering based on energy balance of multi-component process.

13^{th} week

Energy balance of the physical process.

14^{th} week

Energy balance of the process with a chemical reaction.

15^{th} week

Simultaneous mass and energy balances. Computation based on the energy balances with the use of numerical methods.

GENERAL AND SPECIFIC COMPETENCE:

Acquiring basic knowledge of chemical engineering methodology needed to solve practical problems in the process analysis.

KNOWLEDGE TESTING AND EVALUATION:

1. Partial preliminary exams

2. written exam

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student survey

LITERATURE:

1. Himmelblau, D. M.: Basic Principles and Calculations in Chemical Engineering, Prentice Hall, New Jersey, 1982.
2. Felder, R. M., Rousseau, R. W.: Elementary Principles of Chemical Processes, J. Wiley, New York, 1986.
3. Luyben, W. L., Wenzel, L. A.: Chemical Process Analysis: Mass and Energy Balances, Prentice Hall, New Jersey, 1988.

Course: Physical Chemistry II		
Language:		
Lecturer: Krešimir Košutić		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**3**	**45**
Laboratory	**2**	**30**
Seminar	**Part of lecture**	
		Overall: 75
		ECTS: 7

PURPOSE:

Understanding of basic laws and theories of physical chemistry as applied in practice of chemical engineering. The course is not only a collection of facts but an introduction to ways of thinking about the world. Development of capabilities of logical problem solving and equation derivation.

THE CONTENTS OF THE COURSE:

1. week: Description of chemical equilibrium (Gibbs energy minimum), thermodynamic equilibrium constant, Response of equilibrium to temperature (van't Hoff equation)to pressure,
2. week: Response of equilibrium to pressure, NH_3 syntesis, Heterogeneous chemical equilibrium
3. week: Surface phenomena: surface tension, surface films
4. week: Surface phenomena: adsorption, adsorption isotherms (Freundlich, Langmuir, B.ET.)
5. week: First partial exam, Conductivities of electrolyte solutions, weak electrolytes (Ostwald's dilution law)
6. week: Conductivities of strong electrolyte solutions, (Debye-Huckel theory and law)
7. week: Equilibrium electrochemistry, half- reaction and electrodes, electrode potential
8. week: Galvanic cells, electromotive force, Nernst equation
10. week: Physical processes, Diffusion, Fick's first and second law of difusion
11. week:Rates of chemical reaction- definition, rate laws and rate constants, reaction order,and determination of rate law, The chemistry of stratospheric ozone-ozone decomposition
12. week: Kinetics of complex reaction (reverse,-parallel, and consecutive reactions)
13. week: Kinetics of complex reations-chain reaction, Explosion, Polymerization kinetics
14. week: Kinetic and thermodynamic control of reactions, Temperature dependence of reaction rates
15. week: Catalysis and catalyst-homogeneous and heterogeneous catalysis;
Second partial exam

Laboratory work:
1. Surface tension
2. Adsorption (Freundlich isotherm)
3. Determination of transport number (Hittorf method)
4. Conductivity of electrolyte solutions
5. Electromotive force of galvanic cell
6. Determination of constant rate and reaction order of chemical reaction (decomposition of H_2O_2, inversion of sucrose)

GENERAL AND SPECIFIC COMPETENCE:

Describing the basic physical chemistry laws regarding chemical equilibria, surface phenomena (surface tension and adsorption), equilibria in electrolyte solution, and chemical kinetics.
Applying knowledge of mathematics and deriving the equations (clearly describing the physical phenomena under consideration).
Preparing and performing laboratory experiments.
Analysis and interpretation of experimental results.
Preparation of laboratory reports.

KNOWLEDGE TESTING AND EVALUATION:

Entrance and final colloquium in laboratory work, partial exams, oral exam

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student opinion surveys

LITERATURE:

P. Atkins, J. de Paula, Atkin's Physical Chemistry, 8th edition, Oxford University Press, Oxford 2006.

Course: Organic Chemistry II		
Language: English		
Lecturer: Prof. Irena Škorić, Ph.D.		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**3**	**45**
Laboratory	**2**	**30**
Seminar	**-**	
		Overall: 75
		ECTS: 6

PURPOSE: To explain the basic principles of modern organic chemistry and their application in industry and to familiarize the students with structure-activity relationship of organic compounds.

THE CONTENTS OF THE COURSE:

1. Aromatic compounds: properties and reactions; polycyclic aromatic compounds
2. Reactions of aromatic compounds: Basic mechanistic principles of electrophilic aromatic substitution reactions part of which are reactions of halogenations, nitration, sulfonation, alkylation, and Friedel-Crafts acylation; Understanding of impact of substituents on the reactivity and regioselectivity of obtained products.
3. Conjugated unsaturated systems: reactivity of a compound in a reaction of allylic substitution which undergoes by a path of allylic radical intermediate. Explanation of the stability of the allylic radical intermediate by molecular-orbital theory and resonance theory. Application of this reaction in allylic bromination. Understanding of stability of conjugated 1,3-butadiene by delocalization (electron resonance); understanding of principles of electrophilic 1,2- and 1,4-addition on conjugated dienes (kinetic and thermodynamic control of the reaction) and stereochemistry of 1,4-cycloaddition reactions of diene and dienophile (Diels-Alder Reaction).
4. Aldehydes and ketones I. Nucleophilic addition on carbonyl group: synthesis of aldehydes by reduction of starting acyl chloride, ester or nitirile group. Synthesis of ketones from starting alkyne, secondary alcohol or nitrile. Mechanism of acid-catalyzed addition of nucleophile on the carbonyl group of an aldehyde or ketone. Mechanism of hemiacetal and acetal formation; application of acetals as protecting groups in multistep synthesis. Reactions of addition of primary and secondary amine on aldehyde and ketone. Mechanism of addition of hydrogen cyanide on the carbonyl group.

5 Aldehydes and ketones II. Aldole reactions: Chemical reactivity of hydrogen atoms in α-position of carbonyl group and keto-enol tautomerism; reaction of enolate anion; mechanism of acid and base catalyzed enolization; mechanism of acid and base catalyzed reactions of halogenations of aldehydes and ketones; aldole reaction and its synthetic application.

6. Colloquium I
7. Carboxylic acid and its derivatives: Structure and chemical reactivity of carboxylic acid and its derivatives: chloride, anhydride, ester (lactone), amide (lactama) and nitrile; Methods of synthesis of carboxylic acids; synthesis of derivatives of carboxylic acids by interconversion of functional groups in acyl-chloride and the mechanistic principles of nucleophilic elimination reaction on the acyl group.
8. Synthesis and reactions of β-dicarbonyl compounds. Chemistry of enolate anion: Synthesis of β-ketoesters by Claisen condensation and the mechanism of nucleophilic addition and elimination of this reaction; Synthesis of derivatives of malonic acid by Knoevenagel reaction and Michael addition and the mechanism of this reactions; Mannich reaction and its mechanism; Synthesis of enamine by Storck reaction.
9. Amine and like compound with nitrogen: trigonal pyramidal structure of amine and the structure of primary, secondary and tertiary amine and their nomenclature; Familiarization of the structure of aryl amine, basic heterocyclic amine and biologically important amines (derivatives of 2-phenylethylamine, vitamins B_6 and B_1, histamine); Principles of synthesis of amines by alkylation of ammonia, Gabriel synthesis, reductive amination of aldehydes and ketones, reduction of nitrile, oxime and amide and Hofmann and Curtius rearrangement reactions of amide. Reactions which are amides subject to: acid-base reactions, reactions of alkylation, electrophilic aromatic substitution, diazotization; Synthesis of aryl-diazonium salts which are used in preparation of benzene derivatives (Sandmeyer reaction, reaction of diazo copulation).
10. Phenol and aryl-halides: Structure, acidity and nomenclature of phenols; methods of laboratory synthesis of phenol (e.g. Hydrolysis of aryl-diazonium salt), industrial synthesis of phenol (base hydrolysis of chlorobenzene-nucleophilic aromatic substitution reaction); application of phenol in Williams synthesis of ether, Kolbe synthesis of acetyl salicylic acid (aspirin); Claisen rearengament of allyl-phenyl ether; nucleophilic aromatic substitution: addition-elimination mechanism.
11. Colloquium II
12. Heterocyclic compounds
13. Molecular orbitals. Orbital symmetry. Thermal and photochemical cyclization reactions. Electrocyclic and cycloaddition reactions. Principles and stereoscpecifity of electrocyclic reactions in 4 electron systems; reactions of (4+2) and (2+2) cycloadditions on the basis of molecular orbital theory.
14. Carbohydrates: structure and nomenclature of monosaccharide; display mode of structures of monosaccharide by fisher projection and Haworth formulas and conformation formulas in hemiacetal form; Relative and absolute configuration of monosaccharide.
15. Amino acids and proteins: Structure of essential amino acids and understanding of their role as building units in protein synthesis; synthesis of amino acids; enantioselective synthesis and separation of racemic mixtures of amino acids; Structure of primary and secondary polypeptide and amide linkage; method of polypeptide (protein) synthesis.
16. Synthetic polymers; Colloquium III.

GENERAL AND SPECIFIC COMPETENCE:

Students that successfully complete this course will be equipped to:

- recognize and use vocabulary of organic chemistry

- draw correct structural representations of organic molecules
- write acceptable transformations and mechanism for aromatic, carbonyl and heterocyclic compounds
- use their knowledge in stereochemistry while analyzing mechanisms in organic chemistry
- work in a laboratory for Organic synthesis: isolation, purification and identification of organic compounds.

KNOWLEDGE TESTING AND EVALUATION:

Continuous assessment of knowledge via colloquiums; written and oral exam if the student fails on the colloquiums or wants a better grade.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student questionnaire

LITERATURE:

1. T. W. Graham Solomons, Organic Chemistry. 2007, Wiley
2. Clayden, Greeves, Warren and Wothers, Organic Chemistry. 2001, Oxford University Press.
3. S. H. Pine, “Organska kemija” (translated to Croatian by I. Bregovac, V. Rapić), Školsla knjiga, Zagreb, 1994.
4. V. Rapić, “Nomenklatura organskih spojeva”, Školska knjiga, III izmjenjeno i nadopunjeno izdanje (III amended and supplemented edition), Zagreb, 2004.

Name of the course: STRUCTURE AND PROPERTIES OF INORGANIC MATERIALS		
Name of the study programme**:** MATERIALS SCIENCE AND ENGINEERING		
Year of study**: II**		Semester of the study**: IV**
Course teacher: Prof. Hrvoje Ivanković, Ph.D.		
Type of instruction	Type of instruction (number of hours/week L+S+E)	Course lecturers
lectures	2	course teacher
exercises	1	associate teacher
seminars	-	
Course objectives**:** Know the fundamental science and engineering principles relevant to material structure as well as research techniques. Understand the relationship between structure and properties, characterization, and processing and design of materials.		

Course content broken down in detail by weekly class schedule (syllabus):

1. Lecture: Introduction in structure and properties of materials applying MSE diagram. Connection among composition, structure, properties and processing of materials. Classification of materials. Classification of materials based on material structure. Crystal state and amorphous state

2. Lecture: Introduction in crystallography. 3D periodic building of crystals. Unit cell, crystal systems and 14 Bravais crystal lattices. Symmetry elements. Determination of unit cell and crystal system. 3D symmetry and 3D space groups. Crystal planes, Millers indices, interplanar spacing, d.

3. Lecture: Nature of X-ray and its forming. X-ray diffraction Diffraction from crystal lattice. Laue and Bragg equation. Powder and single crystal diffraction, principle and application.

4. Lecture: Intensity of diffraction peaks and influencing factors. Crystallite size determination from peak broadening. Influence remain strains on peak shape. Qualitative and quantitative. Determination of unit cell parameters from XRD pattern.

1. Control test

5. Lecture: Introduction in crystal chemistry. Cubic and hexagonal compact packaging. Materials which can be described by structure of compact packaging. Coordination number and coordination polyhedra. Type of structures described by connection of coordination polyhedra . Paulings rules and covalent structures.

6. Lectures: Description of some typical structures: halite (NaCl), sphalerite (ZnS), fluorite (CaF_2) antifluorite (Na_2O), TiO2, etc. Pervoskite structure. Determination of number of atoms per unit cell. Density calculation.

7. Lecture: Another parameters that influencing crystal structure-overview. Ionic structures-general principes. Coordinated polymeric structure-Sanders model. Valency, bond langht and energy and crystal structure. Influence of nonvalence electrons. Influence of type and bonding energy on engineering properties.

8. Lectures: Defects in crystal. Types of defects . Thermodinamics of defects forming. Point defects. Thermodinamics of forming Schottkys i Frenkels defects. Vacancy and intersticial defects in non-stoichiometryc crystals. 2D defects (surfaces and grain boundaries). 3D defects (precipitates and inclusions). Solid solutions. Substitution and interstitial solid solutions. Experimental methods of investigations of solid solutions (XRD, density measurement, DTA).

2. Control test

9. Lecture: Characterization of inorganic materials- general approach. Techniques overview and their application on solid matter. Thermal techniques: TGA, DTA, DSC and dilatometry. Examples.

10. Lecture: Microscopic techniques. Optical microscopy (polarization or petrography microscope and reflection or metallurgical microscope). Probe preparation and operating principle. Examples. Electron microscopy. History and development of electron microscopy. Comparation between optical and electron microscopy. TEM –transmission electron microscopy. Probe preparation and operating principle. Examples. SEM-scanning electron microscopy. Probe preparation and operating principle. Examples.

11. Lecture : Electrical properties of materials. Dielectric materials. Ferroelectricity. Pyroelecricity. Piezoelektricity. Relationship among fero-, pyro- and piezoelektricity. Applications fero-, pyro- and piezoelektricity. Magnetic properties of materials- introduction and theory. Examples.

12.Lecture: Phase diagrams. Definition. One-component systems (SiO_2). Two-component systems. A simple eutectic systems. Bynary systems with solid solutions ($3Al_2O_3 \cdot 2SiO_2$).

3. Control test

Laboratory exercises:

1.XRD qualitative analysis

2. XRD qualitative analysis of minerals mixture

3. XRD quantitative analysis

4. Determination of unit cell by XRD

5. Thermal methods of analysis (DTA-TG).

6. SEM-scanning electron microscopy

Expected learning outcomes at the level of the course:

- an ability to apply fundamental science and engineering principles relevant to structure and properties of materials.

- an ability to understand 3D form and nature of minerals and amorphous materials.

- be able to calculate parameters relevant for structure, physical properties and chemical stability of materials.

- an ability to use the techniques, skills, and modern engineering tools necessary for precious description the structure and properties of materials.

Student responsibilities**:**

Attending lectures and laboratory exercises.

Type of instruction**:** Lectures and laboratory excercises
Knowledge testing and evaluation: Written and oral exam.
Methods of monitoring quality that ensure acquisition of exit competences **:** Students evaluation
Enrolment requirements and required entry competences for the course: General chemistry and Inorganic chemistry
Required literature: 1. A. R. West, Solid State Chemistry and its Applications, J. Wiley&Sons, New York 1984. 2. C. Hammond, The Basics of Crystallography and Diffraction, Oxford University Press Inc., Oxford 1977. 3. D. R. Askeland and P. P Phule, The Science and Engineering of Materials, Thomson Brooks/Cole, Pacific Grove-CA, USA, 2003. 4.A. Putnis, Introduction to mineral science, Cambridge University Press, UK, 2003

Course: Process Measurement and Control		
Language: English language		
Lecturer: **Ph.D. Nenad Bolf, Assist. Prof.**		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**3**	**30**
Laboratory	**2**	**30**
Seminar	**1**	**0**
		Overall: 60
		ECTS: 5

PURPOSE:

To teach students on modern methods of process control, measurements and diagnostics, metrology and metrological infrastructure.

THE CONTENTS OF COURSE:

System and systems approach. Fundamentals of control theory. Basic control principles of control. Manual and automatic control, feedback control and feedforward control.

Functional structure of control loop: process - measuring sensor/transducer - controller - actuator.

Process dynamics. Mathematical modelling of process and control loop. First and second order systems. Higher order systems Time constant. Dead time.

Measuring and testing; conception, principles and theoretical foundations. Measuring sensor, transducer and instruments characteristics.

Calibration and traceability, measuring error and uncertainty. Reliability, repeatability and reproducibility of measurements.

Legal metrology. Organisation of metrological services, accreditation, certification. Measuring and testing laboratories. Maintenance and calibration of instruments. Quality assurance in measurement and testing. Standards and referent materials.

Measurement, sensor and transducers of temperature, pressure, flow, level, concentration, force. Humidity and moisture measurement.

Controllers. On-off control. Proportional, integral and derivative control. PID controller.

Tuning control systems. Tuning concept. Closed-loop tuning methods. Open loop tuning methods. Integral methods. Control loop stability.

Cascade control. The concept of cascade control. Simple industrial applications. Guiding principles for implementing cascade control.

Feedforward control. Steady-state and dynamic feedforward control. Combined feedforward and feedback control.

Control valves. Types of control valves. Actuators and positioners. Control valve characteristics. Control valve selection and sizing. Control valve dynamic performance.

Special-purpose concepts. Computing components. Ratio control. Override control. Selective control. Split-range control.

Modern control system architecture. System components. Direct digital control (DDC) system. Supervisory control systems. Distributed control systems (DCS). Sequential and batch control.

Process control and process management. Computer-integrated manufacturing (CIM). Statistical process control. Statistical quality control. Statistical process optimisation. Artificial intelligence and expert systems. Fuzzy and neural network-based control.

GENERAL AND SPECIFIC COMPETENCE:

Acquiring knowledge on the modern methods of process measurement and control, control systems, modelling and computer simulations. Using of process measurement and control equipment.

KNOWLEDGE TESTING AND EVALUATION:

Seminars, partial exams, written and oral exams.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student's survey

LITERATURE:

Course material, presentations and simulations on the course web page.

Marlin, T. E. (2005). *Process Control, Design Processes and Control System for Dynamic Performance*, McGraw-Hill

Seborg, D. E., T. F. Edgar, D. A. Mellichamp (2010). *Process Dynamics and Control*, Willey International

Ogunnaike, B. A., W. H. Ray (1994). *Process Dynamics, Modelling, and Control*, Topics in Chemical Engineering, Oxford University Press

MATLAB, *The Language of Technical Computing*, The MathWorks, Inc., 2002.

Course: Electrochemistry		
Language: English		
Lecturers: Sanja Martinez		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**1**	**15**
Laboratory	**1**	**15**
Seminar	**1**	**15**
		Overall: 45
		ECTS: 4

PURPOSE:

- to enable students to gain fundamental and applied knowledge in electrochemistry and electrochemical processes.

- to educate students in electrochemical calculations, electrochemical instrumentation, electrochemical methods.

- provide an experience that encourages development of independent thought and engineering approach to solving complex interdisciplinary tasks in industrial settings and new technologies

- to sustain continuing professional development

THE CONTENTS OF THE COURSE:

1. Week:

   Introduction to Electrochemistry: About the course. Development of electrochemistry as a scientific discipline. The research area of electrochemistry and application of electrochemistry. The basic electrochemical concepts.
   Seminar: solving examples in electrochemical equilibria.

2. Week:

   Conductors and conductivity - Part I: Galvanic circles. Charge transfer through the electrified interface. Principle of electroneutrality. Faraday's law. Mass transfer in the electrolyte.
   Seminar: solving examples in application of Faraday law.

3. Week:

   Conductors and conductivity - Part II: 3 Flow of electric current through the electrolyte. Flow of electric current through the metal. The flow of current through a semiconductor. Intrinsic semiconductors. Extrinsic semiconductors.
   Seminar: solving examples in semiconductors.

4. Week:

   Electrochemical potentials: Electrochemical potential and electrochemical equilibrium. Internal, external and surface potential. Measuring the relative electrode potential. Nernst relation. The definition of the standard electrode potential and reference electrodes.

Seminar: solving examples of application of Nernst equation.

5. Week:

   Models of electrochemical double layer: Helmholtz model. Gouy- Chapman model. Piossonovu -Boltzmann distribution. Stern's model. Capacity of double layer. Electrokinetic effects.
   Seminar: solving examples in electrokinetic effects.

6. Week

   Electrochemical thermodynamics: EMF of a galvanic cell. Thermodynamic parameters of galvanic cells. Thermal effects in galvanic cell.

   Seminar: solving examples in electrochemical thermodynamics.

7. Week:

   First knowledge testing and progress evaluation.

8. Week:

   Electrochemical kinetics: Charge transfer at solid/liquid interface. Butler-Volmer equation. Polarization resistance. Tafel equation. Reversibility and irreversibility.
   Seminar: solving examples in electrochemical kinetics

9. Week:
   Mass transport in electrochemical reactions: Diffusion, migration and convection, Ficks' laws of diffusion. Steady and non-steady states in electrochemical reactions.
   Seminar: examples in mass transport

10. Week

    Electrochemical systems: two electrode systems, three electrode systems, four electrode systems, electrochemical cell design, electrodes, electrochemical instrumentation, prerequisites for doing electrochemical measurements.Electrochemical methods introduction.

    Seminar: examples in electrochemical systems

11. Week
    Electrochemical methods: Chrono methods (chronoamperometry, chronoculometry, chronopotentiometry), cyclic voltammetry, electrochemical impedance spectroscopy.

12. Week
    New phase formation on solid/liquid interface: Metal electrodeposition, electroplating, electrodeposition of polymer layers, nucleation and growth, nucleation kinetics.
    Seminar: phase formation
    Nano-structured polymeric surfaces and supra-molecular chemical structures.
    Laboratory: Desing of conducting polymer battery.

13. Week
    New phase formation on solid/liquid interface: the growth of oxide layers on metals, Pourbaix diagrams.

14. Week
    Practical aspects of electrochemistry: Electrocatalysis, electrochemical energy conversion and storage, industrial electrochemistry

15. Second knowledge testing and progress evaluation.

    Laboratory exercises: (1a) Conductivity of semiconductors; (2) Electrified phase boundary glass / water - Determination of the electrokinetic zeta potential; (3) Electrode process under activation control; (4) The electrode process under diffusion control - 4a. Stationary linear diffusion polarization, 4 b. Non-stationary linear diffusion polarization.

GENERAL AND SPECIFIC COMPETENCE:

General competencies:

- Ability to design and conduct scientific experiment and data interpretation
- Ability to work in a team and development of good communications skills
- Developing of communication skills in written, oral and graphical forms
- Ability to apply gained knowledge in the application of electrochemical methods for scientific and technical purposes
- Recognition of practical engineering problems including economic, social, political and environmental issues.
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Specific competencies

- Knowledge of fundamental concepts in electrochemistry
- Application of electrochemical calculus
- Knowledge of electrochemical methods and electrochemical instruments
- Recognition of the importance of electrochemistry in material science and engineering
- Recognition of electrochemistry in the development of new technologies
- Knowledge of electrochemical literature.

KNOWLEDGE TESTING AND EVALUATION:

Two progress evaluations during the course.

Knowledge testing after the laboratory work.

Written exam.

Oral exam.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student’s poll.

LITERATURE:

1. Internal written materials
2. 1. V. S. BAGOTSKY, Fundamentals of Electrochemistry, John Wiley & Sons, Inc., New Jersey, 2006
3. 2. J. M. Bockris, A.M.K. Reddy, Modern Electrochemistry 1, Ionics, 2nd Ed., Plenum Press, New York, 1998
4. 3. J. M. Bockris, A.M.K. Reddy, M. Gamboa Aldeco, Modern Electrochemistry 2 A, Fundamentals of Electrodics, 2nd Ed., Plenum Press, New York, Kluwer Academics/Plenum Publishers, New York, 2000
5. 4. J. M. Bockris, A.M.K. Reddy, Modern Electrochemistry 2 B, Electrodics in Chemistry, Engineering, Biology and Environmental Science, 2nd Ed., Plenum Press, New York, Kluwer Academics/Plenum Publishers, New York, 2000.
6. 5. C. H. Hamann, A. Hamnett, W. Vielstich, Electrochemistry, 2nd Ed., Wiley VCH, New York, 1998

Course: POLYMERS AND POLYMERIZATION PROCESSES		
Language: English		
Lecturer: Prof. Zlata Hrnjak – Murgić, PhD		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**2**	**30**
Seminar		
		Overall: 60
		ECTS: 5

PURPOSE:

Introduction to the polymerization processes, ie., synthesis of polymers and understanding the basic principles of polymer chemistry.

Understanding the technology of polymerization, kinetics of chain polymerization, condensation and other polymerization. Introducing natural and synthetic polymers. The basic knowledge of characteristics and application of polymers due to the scope.

THE CONTENTS OF THE COURSE:

1st week: Introduction. Classification of polymerization reactions. The nomenclature of the polymers.

2nd week: Radical polymerization, Redox polymerization and redox initiators.

3rd week: Step polymerization, ionic polymerization: anionic and cationic polymerization. Living polymers.

4th week: Copolymerization reaction. Lewis-Mayo equation. Copolymerization diagrams. Q-e scheme.

5th week: Ionic copolymerization. Ring-opening polymerization.

6th week: Bulk polymerization. Suspension polymerization. Emulsion polymerization. Crosslinking reaction.

7th week: 1st partial tests

8th week: Natural polymers: cellulose, natural rubber

9th week: Synthetic polymers: polyethylene, polypropylene

10th week: Polystyrene

11th week: Poly (ethylene terephthalate).

12th week: Polyamides, polyurethanes.

13th week: Synthetic rubbers: EPDM, SBS, nitrile, silicone rubbers.

14th week: Basic principles of waste management.

15th week: 2nd partial test

Lab:

1. Suspension polymerization

2. Graft polymerization.
3. Emulsion polymerization.
4. Hydrolysis of poly(vinyl acetate).
5. Molecular mass separation by fractionation.
6. Determination of the viscosity molecular mass.
7. Titration of double bonds in EPDM copolymers; determination of conversion of monomer into polymer.
8. Swelling of crosslinked polymers.
9. Identification of polymers: pyrolysis, IR spectrometry analysis, burn and density test.

GENERAL AND SPECIFIC COMPETENCE:

Students will gain the competencies of understanding and basic knowledge about the polymer chemistry at the molecular level, the ability to apply the polymerization processes; understanding and analyzing of manufacturing processes of polymer materials.

They will gain the knowledge about the synthesis of polymeric materials, the understanding of the mechanisms of catalytic polymerization processes, engineering materials related to the chemical composition, structure, manufacturing, properties and applications.

KNOWLEDGE TESTING AND EVALUATION:

Partial tests (2 times) (written) or exam (written and/or oral)

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

University of Zagreb student survey

LITERATURE:

1. H. Mark, N. Bikales, C. Overberger, G. Menges, Encyclopedia of Polymer Science and Engineering, John Wiley & Sons, New York, Vol. 1-17, 1985-1989.
2. P. Munk, Introduction to Macromolecular Science, J. Wiley & Sons, N. York, 1989.
3. S. L. Rosen, Fundamental Principles of Polymeric Materials, John Wiley, 1993.
4. C. E. Carraher,Jr., Giant Molecules, J. Wiley Sons, Hoboken, New Jersey, 2003.
5. C. Hall, Polymer Materials, J. Wiley Sons, New York, 1991.
6. I. Franta, Elastomers and Rubber Compounding Materials, Elsevier, New York, 1989.
7. L. A. Utracki: Polymer Alloys and Blends, Hanser Publishers, New York, 1989.

Thermodynamics and kinetics of materials

1. Crystal lattice, ionic crystal lattice energy. Internal energy. Statistical thermodynamics, microstates and macrostates. Multiplicity. Entropy. Thermal and configurational entropy. Enthalpy. Real crystals. Equilibrium concentration of defects. Surfaces. Surface energy.
S1. The calculation of equilibrium concentration of defects.
2. Concepts of system, phase and component. Equilibrium in thermodynamic systems, equilibrium criteria. Gibbs energy. Single-component heterogeneous system, chemical potential of a component. Equilibrium phase diagrams of single-component systems. Degrees of freedom. Gibbs phase rule. Phase transformations, polymorphism.
L1. The determination of heat capacity by differential scanning calorimetry.
3. Multi-component heterogeneous systems, conditions for equilibrium in multi-component heterogeneous system. Equilibrium phase diagrams of two-component systems. Condensed systems. The lever rule. Equilibrium phase diagrams of two component systems without formation of compounds or solid solutions. Eutectic reaction. Microstructure of material obtained by crystallization. Non-equilibrium processes.
S2. Construction of equilibrium phase diagram of simple two-component system using thermodynamic data.
4. Equilibrium phase diagrams of two-component systems with compounds formation. System with chemical compound that melts congruently, system with chemical compound that melts incongruently, peritectic reaction. System with immiscibility in liquid phase, monotectic reaction.
L2. Construction of equilibrium phase diagram of simple two-component system using experimental data (cooling curves).
5. Multicomponent, homogeneous system: solutions. Partial molar properties. Ideal solutions. Regular solutions. Equilibrium phase diagrams of two-component systems with solid sollutions. Systems with formation of solid solution at all proportions.
L3. The dependence of miscibility on temperature.
6. Solid solution systems with partial miscibility. Solid solution systems with the occurrence of polymorphic transformations, eutectoid and peritectoid reactions. Methods of calculation of equilibrium phase diagrams. Experimental methods of determination of equilibrium phase diagrams.
S3. Construction of equilibrium phase diagrams of hypothetic two-component system.
7. Three-component system, the application of leaver rule in three-component systems. System with one eutectic point. Isopletal study in three-component system. System with binary compound that melts congruently. System with binary compound that melts incongruently.
S4. Interpretation of equilibrium phase diagram of three-component system
I. Partial exam
8. Diffusion in crystal lattice. Diffusion processes, heterogeneous diffusion. Diffusion mechanisms, vacancy and interstitial mechanism. Mathematical description of diffusion process. Stationary and non-stationary diffusion flux. Diffusion coefficient. Diffusion in ionic crystals. Diffusion in powder mixtures. Diffusion types: internal diffusion, grain boundary diffusion, surface diffusion.
L4. The determination of diffusion coefficient.
9. Nucleation process. Thermodynamic description of nucleation process. Critical radius. The dependence of nucleation rate on temperature. Homogeneous and heterogeneous nucleation. Nucleation models. Nucleation facilitation strategies.
L5. The determination of nucleation curve.
10. Solid-state reactions kinetics. Specific features of solid-state reactions. Space dimension. The dependence of reaction rate on temperature, activation state. The definition of conversion fraction. Alpha-t curve. Characteristic stages of solid-state reaction advancement.
S5. Computer analysis of alpha-t curve, the determination of reaction model.

11. Resistances to the advancement of solid-state process. Models of solid-state reactions. Geometrical models of solid-state reactions. Kinetic models: diffusion models, phase boundary models, nucleation and growth models.
L6. Kinetic analysis of nucleation and growth process in isothermal conditions.
12. Laws of nucleation, laws of growth. Power law of nucleation and growth. Avrami model. Real and extended conversion fraction. Johnson-Mehl-Avrami model. Other models for nucleation and growth. Isoconversion methods.
L7. Kinetic analysis of nucleation and growth process in isothermal conditions.
13. Kinetic models of solid-state reactions in non-isothermal conditions. Temperature integral. Integral and differential methods. Kissinger method. Model-free methods. Numerical methods.
II. Partial exam

Course: **Characterization of materials (mandatory)** Material Science and Engineering pregraduation; 3rd year (6th semester)		
Language: English		
Lecturers: Danijela Ašperger, Hrvoje Ivanković, Zlata Hrnjak-Murgić, Emi Govorčin Bajsić, Mirela Leskovac		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**3**	**45**
Seminar	**-**	**-**
		Overall: **75**
		ECTS: **6**

PURPOSE:

Familiarizing students with the techniques and principles of work on the individual techniques used for the characterization and identification of the materials. Students acquired knowledge about the properties of materials important for the materials specification for the final application.

Training students for independently work in the lab to monitoring the production/processing materials/products by applying the norms and independent interpretation and reporting about performed analysis.

THE CONTENTS OF THE COURSE:

L-Lectures, **LE-**Laboratory exercises

WEEK (1-3)

Associated professor Danijela Ašperger, Ph.D.

L-1 (2 hours): Introduction. Types of analytical signals. The components of instruments. Clasificatin of instrumental methods.

LE-1 (3 hours): AAS - standard addition method.

L-2 (2 hours): Calibration procedures. Basics of spectrometry.

LE-2 (3 hours): UV-VIS - external standard method

L-3 (2 hours): Electroanalytical methods. Chromatography.

LE-3 (3 hours): Liquid chromatography - a method of internal standard.

WEEK (4-6)

Professor Hrvoje Ivanković, Ph.D.

L-1 (2 hours): Materials analysis by X-rays; X-ray fluorescence (XRF) and diffraction (XRD) analysis - nature of X- rays, formation and absorption of X-rays, theory of XRD, diffraction on single-crystal and powder

L-2 (2 hours): Application of XRD analysis on materials; diffraction on polymer materials and specificity; small angle X-ray scattering (SAXS), diffraction on inorganic nonmetalic materials, qualitative and quantitative mineral analysis

LE-4-5 (6 hours): Recording of unknown sample of crystalline powder by XRD - determination of mineral composition - determination of unit cell parameters of the mineral from XRD scan.

WEEK (6)

PARTIAL TEST 1st partial test

Professor Zlata Hrnjak-Murgić, Ph.D.
Zvonimir Katančić, Ph. D. (LE)

L-1 (2 hours): Introduction to the characterization and identification, relationship structure properties of materials. Sample preparation (solid, liquid, gas). Methods of polymer separation. Spectroscopy methods of analysis: UV, FTIR, NMR - polymer identification and characterization.

WEEK (7-9)

L-2 (2 hours): Determination of molar mass and molar mass distribution of polymers: viscosimetric and GPC methods. Molar mass distibution vs. properties.

LE-6-7 (4 hours): Spectroscopy methods of analysis: UV, FTIR, NMR - polymer identification and characterization. Spectra analysis - specific vibration bands, interpretation and results analysis.

NMR analysis - interpretation of spectra, chemical composition, conformation, structure.

L-3 (2 hours): The chemical, physical, electrical and optical properties of polymers.

LE-8-9 (6 hours): Molar mass determination (Mn, Mw, Mz) and molar mass distribution- GPC method. Results analysis. Viscosimetric determination of the molar mass (Mv).

WEEK (10)

Professor Emi Govorčin Bajsić, Ph.D. (L)
Vesna Ocelić Bulatović Ph. D. and Nina Vranješ Penava Ph. D. (LE)

L-1 (2 hours): Thermal analysis. Thermal properties of materials. Techniques of thermal analysis. Dynamic mechanical technique (DMA). Characterization of materials by DMA. Primary viscoelastic functions. Secundary viscoelastic functions. Time-temperature superposition (TTS). The influence of the compositions and conditions of the measurements on the viscoelastic functions.

LE- 10 (4 hours): Characterization of materials by DMA and TGA technique.

WEEK (11-12)

PARTIAL TEST 2nd partial test

L-2 (2 hours): Differential scanning calorimetry (DSC) technique. Characterization and identification of materials by DCS technique. The type of DSC instruments.

Characteristic transition temperatures, crystallinity. Crystallinity determination. Compatibility. Oxidative stability. Thermal stability.

L-3 (2 hours): Thermogravimetry analysis (TGA). Basics and instruments. Qualitative and

Quantitative TGA. Chemical composition of materials. Thermal degradation of materials. Kinetic of thermal degradation; kinetic parameters. Thermal stability of materials.

LE-11 (3 hours): Characterization of materials by DSC technique.

WEEK (12-15)

Professor Mirela Leskovac, Ph.D.

L-1 (2 hours): Microscopy techniques in material characterization. Overview of microscopic techniques - optical and electronic microscopes - similarity and differences -advantage and disadvantage - application for material characterization.

LE-12 (3 hours): Analysis of different materials - from microscope images obtained by different microscopy techniques.

L-2 (4 hours): Surface characterization of materials - basic definitions: surface and interface - wetting - hydrophobic and hydrophilic properties - contact angle - surface characterization techniques - application in material characterization.

LE-13 (4 hours): Determination of surface free energy of different materials by contact angle measurement - results analysis.

L-3 (2 hours): Mechanical properties of materials - basic definitions - elastic and plastic deformation - viscoelasticity - understanding of relationship between microstructure and mechanical properties (metals, ceramics, polymers, composites).

LE-14 (3 hours): Mechanical properties of different materials - tensile, stress relaxation and cyclic testing - measurements, results analysis.

PARTIAL TEST 3rd partial test

GENERAL AND SPECIFIC COMPETENCE:

General competencies of students - 1. knowledge and understanding of important scientific principles of chemistry and engineering materials: structure, properties and application of materials, 2. ability of independent or team work in the laboratory and the presentation of work in written and oral form, 3. applying knowledge in handling a variety of scientific equipment for material characterization on a safe manner and application standards of engineering practice, 4. ability to apply knowledge in the production process and quality control.

Specific competencies of students – 1. possibility for independent approaches to the analysis of material from the sampling procedures, through choosing the analytical methods, and finaly to the interpretation of the results for the end user, 2. familiarization and acquiring knowledge of the principles of operation of instrumental methods for characterization of materials, 3. understanding and analyzing the basic knowledge regarding the composition, structure and processing properties and applications as well as control of production processes of materials, 4. acquire skills of independent work in the chemical and physical laboratory, 5. gaining awareness about the impact of chemistry and techniques for characterization of materials on the environment and safe mode in the laboratory, 6. possibility of independent presentation laboratory results in written and oral form.

KNOWLEDGE TESTING AND EVALUATION:

Written and oral examination. The possibility of release written part of the exam for collected enough points. The oral part of the exam with the teacher.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student questionnaire.

LITERATURE:

Materials received on the lecture and web site materials. For laboratory exercises the students get prepared templates

ADDITIONAL LITERATURE:

1. D.A. Skoog, J.F. Holler, T.A., Nieman *Principles of Instrumental Analysis, 5th ed.* Saunders College Publishing, 1998.
2. Analitika okoliša, ur. M. Kaštelan-Macan i M. Petrović, HINUS i Fakultet kemijskog inženjerstva i tehnologije, Zagreb, 2013.
3. G. Kümpf, *Characterization of Plastics by Physical Methods*, Hanser Pub. München 1986.
4. B.Wunderlich, *Thermal Analysis*, Academic Press, Inc., London, 1990.
5. A. R. West, *Solid State Chemistry and its Applications*, Wiley and Sons, Brisbane, 1984.
6. K.L. Mittal, *Contact angle, wettability and adhesion*, Utrecth, The Netherlands, 1993.

Course: INORGANIC NON-METAL MATERIALS		
Language: English		
Lecturer: Prof. Nevenka Vrbos,Ph.D		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**pregraduation 6 th term**
Laboratory	**1**	**pregraduation 6 th term**
Seminar		
		Overall: **2+1**
		ECTS: 4

PURPOSE:

Gaining knowledge and understanding of basic elements of chemistry and material engineering. Introduction to basic raw materials for production of inorganic non-metal materials.

Acquiring knowledge about the course of the production process of most important inorganic non-metal materials (mineral binders, glass, and ceramics).

Understanding the importance of recycling processes and requirements of sustainable production.

Gaining knowledge of advanced inorganic non-metal materials (new ceramic materials, glass-ceramics, and biomaterials) and current trends in the development of materials.

THE CONTENTS OF THE COURSE:

Classes of inorganic non-metal materials (INM). Significance and uses of INM in technology. Historic development of materials. Types and classes of inorganic processes. Raw materials for inorganic chemical technology. Rock and minerals, environment, parameters and processes of mineral genesis. Air and hydrate binders. Cement and cement composites. Types, properties and market of ceramic materials. Structure – property relation of glass and ceramics. Traditional and new ceramics .Generic properties of ceramics .Production of ceramics. Firing of ceramics. Glass forming ability and glass crystallization. Classes of glass. Properties of glass. Melting and forming of glass. Glass-ceramics. Controlled glass crystallization. Classes and properties of glass – ceramics .Bio ceramics, classes of bio ceramics. Recycling and sustainable production. Reuse of materials and energy. Ecological aspects of production of inorganic non-metal materials.

Raw materials characterisation by X-ray diffraction and combined thermic analysis. Preparation of cement paste of standard consistency. Setting time determination. Compressive and bending strength determination. Glass-ceramics crystallization sequence. Preparation of hydroxyl –apatite by hydrothermal route. Preparation of foam –glass.

GENERAL AND SPECIFIC COMPETENCE:

Learning the basic concepts of geology, mineralogy and crystallography. Knowledge basic raw materials and manufacturing processes of mineral binders. Knowledge of the production process of glass and ceramics. Knowledge with new materials.

KNOWLEDGE TESTING AND EVALUATION:

Word problems, colloquia, preliminary examination, written examination

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student survey

LITERATURE:

1.P.K.Mehta,Concrete:Structure,Properties,and Materials,Prentice-Hall,New Jersey,1986.

2.A.Đureković,Cement,cementni kompoziti i dodaci za beton,IGH i Školska Knjiga,Zagreb,1996

3.W.Vogel, Kemija stakla, SKTH/Kemija u industriji, Zagreb, 1985. (Naslov originala: Glaschemie, WEB Deutscher Verlag fuer Grundstoffindustrie, 2.auflage, Leipzig, 1983.prijevod R.Laslo i E.Tkalčec

4.H.Yanagida,K.Koumoto and M.Miyayama,TheChemistry of Ceramics,John Wiley &Sons,Chichester,1996

Course: Molecular spectroscopy		
Language: English		
Lecturer: **Prof. Irena Škorić, Ph.D., Prof. Vesna Volovšek, Ph.D.**		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**1**	**15**
Seminar		
		Overall: 45
		ECTS: 6

PURPOSE: To inform students with physical base of molecular spectroscopy and with application of individually each method in chemistry, especially with interpretation of spectra in determination of structures of organic compounds.

THE CONTENTS OF THE COURSE:

1. Interaction of electromagnetic radiation and matter, Electromagnetic spectrum, Quantization of energy and molecular energy levels, Absorption and emission of electromagnetic radiation, Half-width and intensities of spectral transitions.
2. Molecular symmetry, Elements of symmetry, Point groups, Tables of character, Election rules and transition probability.
3. Vibrational spectroscopy, Experimental methods.
4. Molecular vibrations of diatomic molecules, Molecular vibrations of polyatomic molecules, Characteristic vibration.
5. Analysis of vibrational spectra.

COLLOQUIUM

6. NMR spectroscopy: Basic approaches, Nuclear magnetic moment. ^{1}H NMR spectra: Chemical shift and shielding, Integrals, Chemical environment and chemical shift, Magnetic anisotropy, Coupling constant.
7. NMR spectroscopy. ^{13}C NMR spectra: Chemical shifts of carbon-13, integration in ^{13}C NMR spectrum, NOE effect, Heteronuclear coupling of carbon with deuterium, Fluorine-19 and Phosphorus-31.
8. NMR spectroscopy. Spin-spin coupling: Mechanism of coupling, coupling constants of spectrum of first and second order, Long-range coupling.
9. – 11. NMR spectroscopy. Additional chapters in one-dimensional NMR: Exchange of protons in H_2O and D_2O, Tautomerism, Protons on the nitrogen atom, Effect of the solvent on chemical shift; Advanced NMR techniques: DEPT experiment, Two-dimensional spectroscopic methods: COSY, HETCOR

COLLOQUIUM

12. UV/Vis spectroscopy and fluorescence: Instrumentation, Presentation of spectra, Solvents, Chromophores, Effect of conjugation

13. UV/Vis spectroscopy and fluorescence: Woodvards rule for enons, Aromatic compounds, Visible spectrum, Color in compounds

COLLOQUIUM

14. Mass spectroscopy: Mass spectrometer, GC/MS, Mass spectrum, Determination of molecular weight and formula, Effect of isotopes

15. Mass spectroscopy: Fragmentation

COLLOQUIUM

GENERAL AND SPECIFIC COMPETENCE:

Students will be able to analyze obtained results and apply it in determination of structures of organic compounds, by combining spectroscopic methods which they studied in this course.

KNOWLEDGE TESTING AND EVALUATION:

Exam will be held through colloquiums after each major methodological units. Students who do not pass colloquia (total 4) will take written test.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student questionnaire

LITERATURE:

1. Banwell, C. N., McCash, E. M., *Fundamentals of Molecular Spectroscopy*, McGraw-Hill College, 1995.
2. Pavia, D. L., Lampman, G. M., Kriz, G. S., *Introduction to Spectroscopy*, Third Edition, Brooks/Cole Thomson Learning, Australia, 2001.
3. Silverstein, R. M., Webster, F. X., *Spectrometric Identification of Organic Compounds*, Sixth Edition, John Wiley & Sons, Inc., New York, USA, 1997.

Course: Matlab/Simulink		
Language: English language		
Lecturer: **Ph.D. Nenad Bolf, Assist. Prof.**		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**0**	**0**
Seminar	**1**	**15**
		Overall: 45
		ECTS: 4

PURPOSE:

Instruct the students to use the software package MATLAB / Simulink and its advanced functions for the purpose of implementing chemical engineering calculation, display and analysis of measurement data, modelling and process optimization.

THE CONTENTS OF COURSE:

MATLAB/Simulink high-level language. Work environment and basic operations.

Working with matrices and fields. Data structure and programming.

Simulation of the processes and systems. Methods and tools for simulation.

MATLAB advanced functions. Drawing and graphic display. Two-dimensional and three-dimensional graphics. Animation.

Fundamentals of symbolic computations in MATLAB. The functions of symbolic computation. Examples of linear algebra. Solving symbolic equations. Special functions. Working in a graphical environment.

Processing of measurement data in the Curve Fitting Toolbox. Parametric and nonparametric adjustment.

Linear and nonlinear adjustment procedures. Statistical parameters of quality adjustment.

Spline Toolbox. The implementation and application of regression analysis methods.

Case-study. First partial exam.

System Identification Toolbox. The development of dynamic process models using identification methods.

Parametric and nonparametric identification. Model validation.

System Identification Toolbox graphical interface. Example of identification based on data from industrial processes.

Fundamentals of Simulink. Modelling, simulation and analysis of dynamic systems. Interaction of MATLAB and Simulink.

Simulink graphical environment. Design of the process models, graphic, work with blocks. Analysis of the results of simulations.

Examples of linear and nonlinear systems, continuous and discrete models, hybrid systems.

Solving real-life problems. Results analysis.

Second partial exam.

GENERAL AND SPECIFIC COMPETENCE:

Apply information technology and programming fundamentals. Solve engineering problems by applying available software packages. Apply mathematical methods and software in case-study solving.

Apply advanced features for analyzing and displaying data. Perform symbolic functions and calculations. Process and analyze measurement data using software tools. Develop process models in a graphical user interface using Simulink. Resolve examples of continuous, discrete and hybrid systems.

KNOWLEDGE TESTING AND EVALUATION:

homework and seminars, partial exams, written exams

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student's survey

LITERATURE:

Course material, presentations and simulations on the course web page.

Ž. Ban, J. Matuško, I. Petrović, Primjena programskog sustava MATLAB za rješavanje tehničkih problema, Graphis, Zagreb, 2010.

D. Grundler, T. Rolich, A. Hursa. MATLAB i primjena u tekstilnoj tehnologiji, Sveučilište u Zagrebu, Tekstilno-tehnološki fakultet, Zagreb, 2010.

MATLAB, The Language of Technical Computing, The MathWorks, Inc., 2012

S.T. Karris, Introduction to Simulink with Engineering Applications, Orchard Publications, 2006

Course: Introduction to nanotechnology		
Language: English		
Lecturer: Prof. Stanislav Kurajica; Prof. Sanja Lučić Blagojević		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**0**	**0**
Seminar	**1**	**15**
		Overall:45
		ECTS: 4

PURPOSE:

Accepting of the basic terms of nanotechnology. Acquiring knowledge on properties of nanomaterials. Getting acquainted with methods of preparation and characterization of nanomaterials. Acquaint with the most important kinds of nanomaterials and its applications.

THE CONTENTS OF THE COURSE:

1. Concepts of nanoscience and nanotechnology, molecular nanotechnology. History of nanotechnology, Gordon E, Moore, Richard P. Feynman, Eric K. Drexler, R. Kurzweil. Phenomena on nano-level: quantum effects, surface to volume ratio, the dominance of electromagnetic forces.

2. Properties of nanomaterials: physical, mechanical, chemical, optical, electrical, magnetic. Tunelling effect, quantum confinement, quantum dots, nanostructure, magical numbers. Hall-Petch effect, superparamagnetism, giant magnetoresistance, lotos effect.

Laboratory exercise 1. The determination of crystallite size using Scherrer method.

3. Characterization of nanomaterials. Scanning electron microscope, transmission electron microscope, scanning tunneling microscope, atomic force microscope.

Laboratory exercise 2. Synthesis of silver nano-particles.

4. Nano-manufacturing: top-down approach: photolitography, soft litography, microcontact printing, nano-print litography, dip-pen nanolitografy, high-energy milling, PVD, CVD.

Laboratory exercise 3. The preparation of superparamagnetic nano-particles.

5. Nano-manufacturing: bottom-up approach: precipitation, crystallization, colloids, colloid stabilization, solid suspensions, self-assembly, micelles, thin films, self-assembled monolayers, dendrimers, super-latices, sol-gel method. Nanomanipulation, contact and contactless nanomanipulation. The aims for nanomanipulation.

Laboratory exercise 4. Sol-gel synthesis of SiO_2 nanoparticles.

6. Trends in nanotechnology: Nanomaterials (nano-structured materials, smart materials, ageless materials), nanoproducts (electronics, medicine, environment, industrial technology). Nanorobots. The applicative potential of nanomaterials. Sociological

acceptance of nanomaterials. Riscs of nanotechnology Future of nanotechnology.

7. I. Partial exam

8. Carbon nanostructures; Fullerene – synthesis, properties, reactivity, potential application; Carbon nanotubes – molecular and supramolecular structure, intrinsic properties, synthesis, purification, modification, application

9. Nanoscale electronic, Development of microelectronic devices and technology, Structure and operation of MOF transistor; Transistor scaling, Nanoscaled MOFSET transistors;

10. Molecular electronic – possibilities, preparation and investigation of molecular devices; Molecular switches, transistors and similar devices; Electronic with DNA molecules; Single electron electronic devices

11. Nanocomposites – preparation, structure and properties

12.-13. Nanobiotechnology – biomimetic nanostructures, interface with biologic structure and functions: Biomolecular motors – MEMS and biomolecular motors. Operations and functions of motor proteins; Biotechnology of motor proteins; Science and engineering of molecular motors, Engineered devices; Molecular motors in technological application

14. II. Partial exam

GENERAL AND SPECIFIC COMPETENCE:

Knowledge of basic concepts of nanoscience and nanotechnology. Noticing the diversity properties of nano-materials and macro-materials and understand the reasons of these differences. Knowledge of ways of getting nanomaterials on the principle top-down and bottom-up. Knowledge of basic methods of characterization of nanomaterials. Understanding the trends in nanotechnology.

KNOWLEDGE TESTING AND EVALUATION:

Partial exams, written/oral exam

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student questionnarie

LITERATURE:

1. Di Ventra M., Evoy S., Heflin R.J., Introduction to Nanoscale Science and Technology, Springer, 2004.
2. Owens P.,Introduction to Nanotechnology, John Wiley & Sons, 2003.
3. Wilson M., Kannangara K., Smith G., Simons M., Raguse B., Nanotechnology, basic science and emerging technologies, Chapman &Hall, 2002.

Course: Polymeric Biomaterials		
Language: English		
Lecturer: **Assoc. Prof. Elvira Vidović, PhD.**		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**0**	**0**
Seminar	**2**	**30**
		Overall: 60
		ECTS: 4

PURPOSE:

To familiarize with the characteristic terms: biocompatibility, toxicity, biodegradation; the most commonly used materials and their most important characteristics, methods of identification, surface modification and. Synthesis of biodegradable polymers.

THE CONTENTS OF THE COURSE:

1. Introduction.
2. / 3. Definition of biocompatibility, toxicity, biodegradation. In vitro and in vivo biological evaluation of biomaterials.
4. Classification of biomaterials: polymers, silicones, fibers and textiles, hydrogels, natural materials. Classification of polymeric biomaterials: PU, PEG, polydioxanone (PDS), polyhydroxybutyrate (PHB), polyanhydrides, polyorthoesters (POE), polyphosphazenes, politrimetilkarbonat (PTMC), PCL, PLA, PGA, PLGA.
5. The structure, surface and mechanical properties of (bio) polymers. Methods for characterization of properties.
6. Polymer synthesis.
7. Physico-chemical methods of modification of surface properties.
8. Hydrogels: structure, classification.
9. Methods of production of hydrogels.
10. Swelling of hydrogels.
11. Bioresorbable and biodegradable materials.
12. Biodegradation: hydrolytic, oxidative.
13. Application of biomaterials in medicine: an intraocular lens (IOL), compresses, surgical sutures, drug delivery systems, bioelektrode, prostheses, biosensors.
14. Authorship. Legislation. Patents.

GENERAL AND SPECIFIC COMPETENCE:

Knowledge of basic features, types and methods of production of polymer materials used as biomaterials for medical purposes.

KNOWLEDGE TESTING AND EVALUATION:

Continuous assessment through the two exams, written or oral exam.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

student survey

LITERATURE:

1. E. Vidovic: Polymeric Biomaterials, lectures, (www.fkit.hr)
2. R. Auras, L.-T. Lim, S. M. Selke, H. Tsuji, Poly(lactic acid): Synthesis, Structures, Properties, Processing, and Applications, John Wiley & Sons, Inc., Hoboken, New Jersey, 2010.

Graduate study programmes

Course: Surface engineering		
Language: English		
Lecturer: Prof. Sanja Lučić Blagojević; Prof. Mirela Leskovac		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**2**	**30**
Seminar	**1**	**15**
		Overall:75
		ECTS: 7

PURPOSE:

Gaining knowledge about the surface phenomena, where by surface engineering structure and properties of materials can be modified in general. The basic approach for the development of materials is controlled change of the interfacial properties from nano-level to the micro-and macro-levels. Understanding of tribology provides the necessary knowledge about the mechanisms of friction and wear of materials.

THE CONTENTS OF THE COURSE:

L – lecture; LE – laboratory exercise; S-seminar

L (1-2): Surface phenomena. The processes at surfaces. Surface tension and surface energy. Terminology. Interfacial energy. Wetting and spreading. The surface energy and work of adhesion. Young's equation and the work of adhesion. The characteristics of the surface and the contact angle. Characterization of surfaces.

L (3-4): Adhesion. Definition and theory. The science of adhesion. Basic and practical adhesion. Theories of adhesion: mechanical, adsorption, chemical, electrostatic, diffusion, other theories. Adhesion at interfaces in complex systems in use.

S (1)

LE: LE - Surface tension; LE - Surface phenomena in composites - contact angle; LE - Surface phenomena in composites - gas chromatography; LE - Determination of adhesion parameters

1st partial exam

L (5-6): Polymer surface. Thermodynamics of polymer surfaces. Surface modification of polymers. The reasons for the modification. Pretreatment of the polymer surface. Methods of pretreatment: mechanical, chemical, oxidation, plasma. Identification of the surface. UHV surface analysis. Characterization of polymer surfaces. Characterization methods: AES, XPS, SIMS, EPMA, ATR and others.

L (7-8): Polymer-polymer interface. Examples. Thermodynamics of polymer interphase. Compatibility of the polymer. Symmetrical polymer interface. Self-adhesion. Asymmetrical polymer interface. The thickness and strength of the interface. The diluted polymer solution / solid. The conformation of the polymer chains at the interface.

L (9): Interface in polymer blends. Miscible and immiscible polymers. Interphase in the blends.

L (10): Interface in polymer composites. The impact on the adhesion of the morphology, mechanisms of failure, and mechanical properties. Influence of interfacial properties: microcomposites vs. nanocomposites. The types of polymer nanocomposites. Modification of interface in nanocomposites. New advanced materials.
S (2)
LE: LE - Pretreatment of surfaces; LE - Morphology of the composite system; LE - Failure in composites; LE - Mechanical properties of composites; LE- Interaction coefficients in composites
L (11-12) Adhesive compounds. Types of adhesives. Modification of interface in adhesive joints. The influence of the environment and aging. Testing of adhesive joints.
LE: LE – Testing of adhesive joint.
2nd partial exam

L (14-15): Tribology. Principles and industrial importance of tribology. Micro-and nano-tribology. Structure and properties of solids, characterization of the contact surface and adhesion as a function of the tribological behavior. Friction. The laws of friction in sliding and rolling surfaces. Wearing. The basic mechanisms of wear: adhesion, abrasion, fatigue, tribocorrosion. Wearing of materials: metals and alloys, ceramics, polymers, plastics. Surface treatment. The criterion for selecting lubricants and surface treatment techniques in the industry. The specificity of polymer surfaces and new techniques for measuring tribological properties.
S (3)
LE : LE - Tribological properties of materials - friction; LE - Tribological properties of materials - wear
3rd partial exam

GENERAL AND SPECIFIC COMPETENCE:

General competencies of students are extended with knowledge about phenomena of surface and interface, as well as the possibilities of engineering changes which alter the structure and properties of surfaces and materials as a whole - as an innovative way to new materials.
Specific competencies are related to exploring and modifying of the processes that occur on surfaces in industrial applications such as adhesion, friction, wear, etc.., which are crucial in the adhesion of connecting elements, processing, tribology and surface protection materials.

KNOWLEDGE TESTING AND EVALUATION:

Partial exams, written exam

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student questionnaire.

LITERATURE:

1. V. Kovačević, S. Lučić Blagojević, M. Leskovac, Inženjerstvo površina, interna skripta, 2008.
2. K.L. Mittal, Polymer Surface Modification; Relevance to Adhesion, VSP, Netherland, Vol.2, 2000.
3. Y.S. Lipatov, Adhesion of Polymers at the Interface with Solids, in Polymer Reinforcement, ChemTec Publishing, Toronto, 1995.
4. V. Ivušić, Tribologija, Hrvatsko društvo za materijale i tribologiju, Zagreb, 1998.
5. B. Bhushan, Principles and Applications of Tribology, John Wiley & Sons, New York, 1999.
6. L.H. Sperling, Introduction to Physical Polymer Science, Wiley Interscience, New Yersey, 2006.

Course: Petroleum and petrochemical products		
Language: English		
Lecturer: **Full Prof. Katica Sertić Bionda, PhD.; assoc. prof. Elvira Vidović, PhD.**		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**3**	**45**
Laboratory	**2**	**30**
Seminar	**0**	**0**
		Overall: 75
		ECTS: 7

PURPOSE:

Introduction to the theoretical and practical facts of crude oil processing and petrochemical production, the properties of their main products, based on a synthesis of chemical engineering knowledge.

THE CONTENTS OF THE COURSE:

1. Introduction to the processing of crude oil. The origin, exploration and chemical composition of the oil.
2. The processes and products of the first step of oil processing (atmospheric and vacuum distillation).
3. Products of process of thermal cracking (visbreaking, coking).
4. Catalytic cracking; products (gas, naphtha, cyclic oil): the impact of raw materials, catalysts and the process variables on the yield and composition.
5. Production of gasoline components by processes of reforming, isomerization and alkylation.
6. Motor gasoline and diesel fuel; application, composition, properties, preparation.
7. Other products of processing of oil; fuel oil, bitumen, coke and lubricating oils.
8. Introduction to the petrochemical industry: raw materials, processes, products.
9. Natural gas: composition and distribution, processing operations. Liquefied natural gas (LNG). Liquefied petroleum gas (LPG).
10. Methane based products. Chlorinated hydrocarbons.
11. Syngas. Hydrogen. Ammonia. Synthetic gasoline and diesel fuel.
12. Production of olefins by steam cracking (pyrolysis).
Products of ethylene: polyethylene, vinyl chloride, ethylene oxide, ethylene glycol.
13. Products of propylene: polypropylene, propylene oxide, acrylic acid, acrylonitrile. Proces and products of oxosynthesis.
C4 hydrocarbon products. Butadiene.
14. Aromatics hydrocarbons (BTX). Products of benzene. Products of toluene.

Products of xylene.

GENERAL AND SPECIFIC COMPETENCE:

The adoption and application of theoretical knowledge about the main products of oil refineries and petrochemical industries, as well as the reaction pathways and technological scheme for their production.
To facilitate the involvement in working processes in oil and petrochemical industries and handling with products.

KNOWLEDGE TESTING AND EVALUATION:

Continuous assessment by four tests, written or oral exam.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student survey.

LITERATURE:

K. Sertić-Bionda: Petroleum refining, lecture for students (www.fkit.hr).

K. Sertić-Bionda: Petroleum refining, excerses for students (www.fkit.hr).

E. Vidović: Petrochemical products, lecture (www.fkit.hr)

P. Leprince: Petroleum refining, Vol. 3, Conversion processes, Technip, Paris, 2001.

Course: Physical chemistry of polymers

Language:

Lecturer: Marica Ivanković

TEACHING	WEEKLY	SEMESTER
Lectures	3	45
Laboratory	2	30
Seminar	0	0
		Overall: 75
		ECTS: 6

PURPOSE:

Understanding of physical and chemical properties of polymers based on simple molecular models

THE CONTENTS OF THE COURSE:

1. week: Introduction: basic terms, features of polymer structures
2. week: Internal rotation in polymer molecules, intermolecular and intramolecular interactions, thermodynamic and kinetic flexibility of polymer chain
3. week: Conformations of polymer molecules; Ideal and real polymer chains: polymer chain models, coil dimensions, excluded volume.
4. week: Molecular weights of polymers: averages, distribution, distribution functions.
5. week: Polymer solutions: swelling and dissolution of polymers, «theta» solvent, good and poor solvents, solubility parameter.
6. week: Viscosity of dilute polymer solutions: specific viscosity, reduced viscosity, intrinsic viscosity (limiting viscosity number); Models of polymer molecules in shear flow: Impenetrable sphere (nondraining); Penetrable coil (free draining
7. week: Osmotic pressure of dilute polymer solutions
8. week: First partial exam
9. week: Thermodynamics of polymer solutions: enthalpy, entropy, Gibbs free energy of mixing, Flory-Huggins theory
10. week : Flory-Huggins interaction parameter, thermodynamic stability of polymer solutions, phase equilibria, phase diagrams.
11. week: Methods of estimating polymer molecular weight distribution: fractionation.
12. week : Gel permeation chromatography.
13. week: Polymer blends: thermodynamics of binary polymer blends, phase equilibria, phase diagrams.
14. week: Liquid crystalline polymers
15. week: Second partial exam

Laboratory work:

1. Identification of polymers from solubility tests

2. Swelling kinetics of polymers
3. Viscosimetry, intrinsic viscosity, viscosity- average molecular weights
4. Viscometric determination of solubility parameters, three-dimensional solubility parameters.
5. Osmometry, number-average molecular weight, second virial coefficient
6. Gel permeation chromatography

GENERAL AND SPECIFIC COMPETENCE:

Ability to characterize polymers using different methods,
Preparing and performing laboratory experiments.
Analysis and interpretation of experimental results.
Preparation of laboratory reports

KNOWLEDGE TESTING AND EVALUATION:

Two written partial exams, laboratory reports, written exam.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student opinion surveys

LITERATURE:

1. S.F.Sun, Physical chemistry of macromolecules, 2nd edition, Wiley-Interscience, 2004

2. L.H. Sperling, Introduction to physical polymer science,3rd edition, Wiley-Interscience, 2001.

The chemistry of silicates

1. Importance of silicates, reasons for multitudinous and diversity of silicates. Environment, conditions and processes of silicate minerals genesis.
2. Silicon: obtaining and properties. Technical silicon. Semiconductor silicon, CVD process, Chochralski process, zone melting. Solar silicon.
3. The nature of chemical bond between silicon and oxygen, (SiO_4)-tetrahedron. Principles and ways of (SiO_4)-tetrahedron connecting. Criteria of stability of complex silicate structures.
L1. X-ray diffraction analysis of silicates.
4. The classification of silicates: chemical, natural, structural, other methods of silicate classification. Silicates nomenclature. Structure formula of silicates.
L2. FTIR spectroscopy analysis of silicates.
5. Nesosilicates: olivine, zircon, garnets, silimanite group.
L3. The determination of mulite composition using lattice parameters.
6. Sorosilicates, cyclosilicates. Inosilicates: pyroxene, pyroxenoides, amphiboles. Precious and semi-precious gemstones.
7. Phylosilicates: kaolinite, serpentine, pyrophilite, talc, dioctahedral smectites, mica, hydro-mica, chlorites.
I. Partial exam.
8. Genesis of layered silicates, phenomenon of clays ion exchange. Clay-water system: plasticity, viscosity, flow.
L4. The stability of clay suspension.
9. Tectosilicates: feldspars, feldspathoides, zeolites.
10. Polymorphic modifications of SiO_2, Fenner's diagram. Quartz, quartz raw materials.
11. Synthetic amorphous silica: pyrogenic silica, silica-sol, silica-gel, precipitated silica.
L5. The preparation of silica sol and gel.
12. Inorganic silicon compounds: Soluble alkali silicates, silicon alloys, silicides, SiO, silicon carbide, silicon nitride, silicon hydride, silanes, silicon halogenides.
L6. The formation and properties of metal silicate hydrates.
13. Organosilicon compounds: organosilanes, organochlor silanes, organo alkokoxysilanes, organo-siloxanes. Silicones: silicone oil, silicone resin, silicone rubber.
L7.The preparation of silicone rubber.
II. Partial exam.

Course: Composite materials		
Language: English		
Lecturer: Jelena Macan		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**2**	**30**
Seminar	**0**	**0**
		Overall: 60
		ECTS: 6

PURPOSE:

Introduction to multicomponent systems – polymer, metal and ceramic matrix composites, their application, production and disposal. Integration of the previous understanding of materials, understanding the interconnectedness of microstructure, properties and modes of production of the composite materials.

THE CONTENTS OF THE COURSE (by weeks)**:**

1. Introduction to composite materials: type of materials depending on matrix and filler, basics of interface and adhesion.

2. Polymer matrix composites. Dependence of properties on structure.

3. Thermoset matrix composites, thermoset resins used in production of composites, curing reaction of the resins.

4. Thermoplastic matrix composites, types of matrices, rheology of thermoplast melts. Fillers and reinforcements in polymer matrices.

5. Interface in polymer composites. Improvement of bonding between the matrix and fillers, modification of interface.

6. Polymer nanocomposites. Types and production of nanocomposites. Organic-inorganic hybrid materials and sol-gel process.

7. Production processes for thermoset matrix composites.

8. Production processes for thermoplastic matrix composites. Application and future of polymer composites.

9. 1st partial exam. Structure and properties of inorganic materials.

10. Solid solutions, crystal structure defects, phase diagrams.

11. Metal matrix composites – types and properties. Interface in metal matrix composites.

12. Ceramic matrix composites. Reinforcements, reinforcement mechanisms, fracture mechanisms for ceramic materials and composites. Ceramic

nanocomposites.

13. Production of metal matrix composites, procedures in liquid and solid state, deposition techniques, reactive processing. Production of ceramic matrix composites.

14. 2nd partial exam and calculation test. New composite materials. Surface structuring, smart materials, metamaterials, biomimetic materials.

15. Seminary works by students.

Laboratory exercises:

1. Curing of thermoset matrices for composite materials
2. Identification of polymers in a composite (multilayer) film
3. Modification of layered silicate as a filler in polymer matrix
4. Modification of nanoparticles as filler in polymer matrix
5. Modification of materials surface by deposition of sol-gel coatings

GENERAL AND SPECIFIC COMPETENCE:

Connecting the individual facts into wider knowledge and understanding. Spotting the interconnectedness of structure and properties of composite materials and application of this in designing new materials. Planning and carrying out of experiments, analysis of experimental data. Writing a seminary work on a given subject.

KNOWLEDGE TESTING AND EVALUATION:

Partial exams. Calculation test. Oral exam. Students can earn part of their credits by writing the seminary work or through the e-learning system.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student questionnaire.

LITERATURE:

1. T. W. Chou, Eds., Structure and Properties of Composites, Vol. 13 of Materials Sciencand Technology, R. W. Cahn, P. Haasen and E. J. Kramer, Eds.,VCH Publishers Inc., New York, 1993.

2. L. A. Pilato, M. J. Michno, Advanced Composite Materials, Springer-Verlag, Berlin, 1994.

3. I. S. Miles, S. Rostami, Eds., Multicomponent Polymer Systems, Longman Scientific & Technical, Bath Press, Avon, 1992.

Croatian language literature is also available.

Course: Polymer nanocomposites

Language: English

Lecturer: Prof. Sanja Lučić Blagojević

TEACHING	WEEKLY	SEMESTER
Lectures	2	30
Laboratory	0	0
Seminar	1	15
		Overall: 45
		ECTS: 4

PURPOSE:

To introduce students with access of design of nanocomposite polymer materials aiming to achieve specific properties. The objective can be achieved by integrating knowledge from the field of polymer materials, inorganic materials, and knowledge about the modelling of the interface polymer / filler.

THE CONTENTS OF THE COURSE:

L1 - Polymeric materials. The importance and application of polymeric materials. Classification of polymer materials by origin, by application properties, according to the type of repeating units, according to the forms of macromolecules. Mechanisms of polymerization: step, chain; homogeneous and heterogeneous processes of polymerization. The structure of polymers: configuration and conformation of macromolecules. Super-molecular structures. Physical properties of polymers. Additives to polymer materials. Fillers as modifiers of properties.

L2 - Differences between micro and nanocomposites. Polymer Composites. Interphase polymer - filler: mechanisms of adhesion, the application of adsorption theory. Thermodynamics of interfacial free energy, coefficient of wetting, thermodynamic work of adhesion. Chemisorption theory. Differences between nanocomposites and microcomposites: filler particle size, size of the interface, morphology, fraction of matrix in the interphase layer.

L3-5 The types of nanofillers. *Carbon nanotubes*: molecular and supramolekulna structure, properties (mechanical properties, electrical properties). Processing of nanotubes: laser ablation, arc discharge, chemical vapor deposition. Composition and purification of the reaction products. Surface modification (covalent and non-covalent)

The layered nanofillers: types, structure, organic modification of layered nano-filler. *Equi-axed nanofillers*: types, production, surface modification.

Quantum dots: types, structure, quantum effects, properties. Surface modification of quantum dots: with amphiphilic polymers, multidentate polymeric ligands, polymers functionalized at the ends of the chain, quantum dots encapsulated by dendrimers.

1st partial exam

L7-9 Preparation of polymer nanocomposites. The distribution and the dispersibility of fillers in the polymer matrix. *Preparation process for composites with carbon*

nanotubes: preparation of the solution, stirring the mass of the polymer, the mixing in the melt, in situ polymerization.
Preparation of nanocomposites with layered nano-fillers: intercalated and exfoliated morphology, instrumental techniques for morphology investigation. Methodology and thermodynamics of individual processes: intercalation of polymer or prepolymer, in situ intercalation polymerization, melt intercalation. The impact of factors on the morphology of the melt intercalation process. The degradation of the system during the preparation of the melt intercalation.
Preparation of polymer nanocomposites with equi-axed nano-fillers. The process for preparing the melt and solution, in situ polymerization of the polymer, the in situ polymerization of the inorganic phase is formed.
Preparation of nanocomposite system quantum dot / polymer. Quantum dots in polymer colloids - a methodology for preparing nanocomposites with different methods, advantages and disadvantages of different methods of preparation. Systems of layer-by-layer quantum dot / polymer. Controlled binding of polymer layers and quantum dots. Quantum dots in polymers bulk and thin polymer films.

L10-11 Properties and application of polymer nanocomposites. Mechanical properties: the influence of types of nano-filler, filler particle size and thermodynamics of the polymer / filler morphology, failure mechanisms and features of the mechanical behavior (modulus, tensile strength, toughness). Effect of nanofiller on the permeability of gases and liquids: the concept of tortuous diffusion. Dimensional stability of nanocomposites. The thermal stability of the nanocomposites. Effect of nanofillers on flammability of polymers. Electrical properties. Optical and optoelectronic properties.

L12 2nd partial exam

L13-15 Student seminars

GENERAL AND SPECIFIC COMPETENCE:

The course develops the general students' competence of analysis and synthesis of scientific knowledge and presentation in oral form.

Specific competencies courses include connecting knowledge engineering polymer materials and surface and interfacial engineering in multiphase polymer systems, broadening and deepening the knowledge of the structure, properties, production and application of polymer nanocomposites as advanced materials, and knowledge about the selection of techniques and methods for the characterization of multiphase systems and quality control of the final products.

KNOWLEDGE TESTING AND EVALUATION:

Partial exams, writing and oral exam

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student questionnaire.

LITERATURE:

1. P. M. Ajayan, L. S. Schadler, P. V. Braun, Nanocomposite Science and Technology, Wiley – VCH, 2003.
2. T. J. Pinnavaia, G. W. Beall, Polymer-Clay Nanocomposites, John Wiley and Sons Inc., 2001.
3. A. I. Nakatani, R. P. Hjelm, M. Gerspacher, R. Krishnamoorti, Filled and Nanocomposite Polymer Materials, Vol.661, Materials Research Society, 2001.
4. R.Vaia, R. Krishnamoorti, Polymer nanocomposites: Synthesis, Characterization and Modeling, American Chemical Society, 2001.
5. Y. S. Lipatov, Polymer Reinforcement, Chem. Tec. Publishing, Ontario, 1995.

Course:	**Additives for polymer materials (optional)** Material Science and Engineering, graduation; 1st and 2nd year		
Language: English			
Lecturer: Mirela Leskovac			
TEACHING	**WEEKLY**	**SEMESTER**	
Lectures	**2**	**30**	
Laboratory	**1**	**15**	
Seminar	**-**	**-**	
		Overall: 45	
		ECTS: 4	

PURPOSE:

Familiarizing with the most important additives which are used for modification, improvement of properties and resistance of polymer materials and their products, focused on mechanisms of their action and application.

THE CONTENTS OF THE COURSE:

L-1 An introduction to polymer additives. Classification of additives for polymer materials and products, principles of their action, properties and application; ecological and economical impacts of polymer additives.

L-2 Modifiers of physical properties of polymer materials; principles of their action, classification, properties and applications. The polymer additives efficiency.

L-3 Improvement/ Modification of mechanical properties. Impact modifiers: toughness and macromolecular modifiers. Additives for improvement of strength, processibility and stability: fillers, reinforcing agents and coupling agents.

L-4 Blowing agents; chemical and physical blowing agents; characteristics and factors acting on blowing.

L-5 Plasticizers: Solubility parameter, theory of plasticization, primary and secondary plasticizers. Classification of plasticizers. Plasticizer efficiency.

L-6 Modifiers of optical properties: dyes, pigments and optical brighteners. Classification, properties and application. Criteria for selection of pigments.

L-7 Modifiers of surface properties. Lubricants: reducing of friction, surface abrasion and adhesion. The effect of lubrication on the polymer processing.

L-8 Conductivity: antistatic and conductive additives, action mechanism, classification, properties and application.

L-9 Additives that have a protecting effect against polymer aging and degradation; action mechanism, classification, properties and application.

L-10 Effects of chemically and physically active media, effect of ionizing radiations, mechanical and thermal degradation.

L-11 Heat stabilizers; the influence of heat stabilizers. Thermo-oxidative degradation: action mechanism of antioxidants.

L-12 Photo-oxidative degradation: action mechanism of UV stabilizers, classification and application.

L-13 Flammability: burning mechanism of polymers, flame retardants; action mechanism of retardants, classification, properties and applications.

L-14 Microbiological degradation: action mechanism of biocides; properties and application.

L-15 Methods used to incorporate additives into polymer matrices. Ecological aspects of application of additives for polymer materials and their products. Technical trends and new market requests.

Laboratory exercises:

I. PROPERTIES OF POLYMER ADDITIVES

LE-1) Surface phenomena and surface tension measurement by pendant drop method.

II. OXIDATIVE STABILITY OF POLYMER MATERIALS

LE-2) Influence of additives on the oxidative stability of materials; determination of oxidation induction time, OIT

LE-3) Influence of additives on the oxidative stability of materials; determination of oxidation induction temperature, OIT*

LE-4) Influence of additives on the thermal stability of polymer materials.
LE-5) Polymer flammability - Limited oxygen index (LOI)

III. PRINCIPLES OF POLYMER PLASTICIZATION

LE-6) Influence of plasticizers on the polymer material properties.
LE-7) Evaluation of plasticizers efficiency.
LE-8) The influence of plasticizers on the polymer surface properties (study of plasticizers migration).

L-Lectures, **LE**-Laboratory exercises

GENERAL AND SPECIFIC COMPETENCE:

Acquiring knowledge required to obtain satisfactory properties of polymeric materials and quality. Knowledge relevant to the selection of additives and features crucial for ensuring the quality and stability of engineering polymers depending on the specific requirements of the application.
Specific competencies include training of future experts to apply the acquired knowledge in the production process and quality control.

KNOWLEDGE TESTING AND EVALUATION:

Partial exams; written / oral exam.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student questionnaire.

LITERATURE:

1. M. Leskovac, *Dodatci za polimerne materijale i proizvode*, Interna skripta, 2008.
2. Z. Janović, Polimerizacije i polimeri, Hrvatsko društvo kemijskih inženjera i tehnologa, 1997.
3. L. H. Sperling, Introduction to Physical Polymer Science, Wiley Interscience, New Yersey, 2006.

ADDITIONAL LITERATURE:

4. Jan C.J. Bart, Additives in polymers (Industrial Analysis and Applications), John Wiley & Sons Ltd, England 2005
5. J. T. Lutz, R.F. Grossman, Polymer Modifiers and Additives, Marcel Dekker, 2001.
6. J. Štepek, H. Daoust, Additives for Plastics, Springer-Verlag, New York, 1983.

Course: PACKAGING POLYMER MATERIALS		
Language: English		
Lecturer: Prof. Zlata Hrnjak-Murgić, PhD		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**0**	**0**
Seminar	**1**	**15**
		Overall:45
		ECTS: 4

PURPOSE:

Introducing students to the packaging polymer materials, their role and their importance in the areas of packaging and their applications.

THE CONTENTS OF THE COURSE:

1st week: Introduction. Classification of packaging, role of the packaging

2nd week: Properties of packaged goods, properties of packaging materials

3rd week: Labelling of packaging and consumption

4th week: Properties and characteristics of the packaging material

5th week: Barrier properties, biopolymers

6th week: Polymers for packaging materials

7th week: 1st partial test

8th week: Biodegradable polymers.

9th week: Layered packaging materials

10th week: Technological of processing

11th week: Packaging materials and waste - characterization

12th week: Management of packaging materials

13th week: Recycling of packaging materials.

14th week: 2nd partial test

Seminar: Making presentations and / or written seminar paper on a given topic

GENERAL AND SPECIFIC COMPETENCE:

The students will learn about polymer packaging materials and become competent to work in the field. They will gain an insight into the field of polymer waste management.

Specific competencies: students will gain knowledge and competence about the

properties and importance of packaging polymer materials, acquire knowledge for their quality control.
KNOWLEDGE TESTING AND EVALUATION: Partial tests (2 times) (written) or exam (written and/or oral)
MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS: University of Zagreb student survey
LITERATURE: 1. O.G. Piringer, A. L. Baner, Plastic Packaging Materials for Food: Barrier Function, Mass Transport, Quality Assurance and Legislation, J. Wiley & Sons, N. York, 1999 2. K. Galić, N. Ciković, K. Berkocić, Analiza ambalažnog materijala (Analysis of packaging materials), Zagreb, 2000 3. A. L. Andrady, «Plastics and the Environment», J. Wiley & Sons, Hoboken, New Jersey, 2003 4. C. D. Marotta, Packaging Materials, in H.F. Mark, N. M. Bikales, C.G. Overberger i G. Menges, Encyclopaedia of Polymer Science and Engineering, J. Wiley & Sons, N. York, 1987, Vol. 10, p.684. 5. Science Direct, Web of Science

Course (optional):	**Nondestructive methods of chemical analysis in art and archaeology, Material Science and Egineering (1st year, 1st semester, mag. ing. cheming.)**	
Language: English		
Lecturer: Associated professor Danijela Ašperger, Ph.D.		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**15**
Laboratory	**1**	**15**
Seminar	**0**	**-**
Field work (days)	**4 visitations x 2 hours**	**Part of lectures and laboratory exercises.**
		Overall: 45
		ECTS: 4

PURPOSE:
Introduce students to access materials analysis which does not allow classical sampling and through this classical preparation of samples for analysis. Application to restoration and conservation work.

THE CONTENTS OF THE COURSE:

Lectures:

1. Introductory lecture; introduction to the course, with terms of examination, instructions for exercises. The role of analytical chemistry in art and archeology, the role of scientific analytical work in education of restorers-conservators.
2. Tasks of laboratory, laboratory techniques and methods. Introduction to analytical system: access to object which cannot be damaged, preparing the object for analysis, microsampling, laser microsampling, electrochemical microsampling.
3. Introduction to the application of classical and modern instrumental techniques for determining the chemical composition and surface analysis of the object: spectroscopic, electroanalytical and separation methods.
4 Application of atomic and molecular spectroscopy in restoring and preserving objects of historical and cultural importance.
5. Applying of X-ray fluorescence and diffraction in restoring and preserving objects of historical and cultural importance.
6. Application analysis of ion beams (PIXE, PIGE, RBS) and neutron activation analysis in the restoration and preservation objects of historical and cultural importance.
7. Application of Infrared and Raman spectroscopy for the restoration and preservation objects of historical and cultural importance.
8. Application of photographic research in restoring and preserving objects of historical and cultural importance: infrared photography and reflectography.
9. Application of photographic research in restoring and preserving objects of historical and cultural importance: ultraviolet reflectography and fluorescence.
10. Application of photographic research in restoring and preserving objects of historical and cultural importance by x-ray radiography and X-ray computer

tomography.
11. Application of separation chromatographic methods for restoring and preserving objects of historical and cultural importance.
12. Impact of microorganisms and other impacts on the deterioration of objects of historical and cultural importance - fumigation of art.
13. Dendrochronology - absolute and relative dating of the past.
14. Students seminars on a given topic.
15. Final exam of lectures and of laboratory exercises.

Laboratory exercises:
1. Anodic sampling and thin layer chromatography analysis of archaeological bronze.
2. Sample preparation for binder's analysis by thin layer chromatography – ultrasonic extraction.
3. Analysis of binders - resins, oils, waxes in the castle wall murals Brezovica.

Field work:
1. Visitation to Archaeological Museum - analysis of mummies.
2. Visitation to Natural science laboratory in the Croatian Conservation Institute - access to the object from sampling to analysis and writing reports.
3. Visitation to the Croatian State Archives (Palace Lubinsky) - a central laboratory for restoration and conservation of paper and leather.
4. Visitation to the Ethnographic Museum - a central laboratory for restoration and conservation of textiles and other supporting items (jewelry, feathers).

GENERAL AND SPECIFIC COMPETENCE:
Introduction to the analysis of works of art and archaeological objects, for which is usually impossible to take macro samples and through this is emphasized the importance of using methods that enable analysis "*in situ*" or the analysis after micro-sampling of objects.

KNOWLEDGE TESTING AND EVALUATION:
Written and oral examination. The possibility of release written part of the exam if you collect enough points. The oral part of the exam with the teacher.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:
Student questionnaire.

LITERATURE:
Lectures:
1. V. Desnica, Instrumentalna analiza, Interna skripta, Akademija likovnih umjetnosti, Zagreb, 2012.

Laboratory exercise:
2. D. Ašperger, Nedestruktivne metode kemijske analize u umjetnosti i arheologiji, Interna skripta, Fakultet kemijskog inženjerstva i tehnologije, Zagreb, 2011.

ADDITIONAL LITERATURE:
1. E. Ciliberto, G. Spoto, Modern analytical methods in art and archeology, Wiley-Interscience, New York, 2000.
2. K. Janssens, R. van Grieken (Eds), Non-destructive microanalysis of cultural heritage materials, Elsevier, 2004.

Course: Conducting polymers-synthetic metals		
Language: English		
Lecturers: Marijana Kraljić Roković		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**1**	**15**
Seminar	**0**	**0**
		Overall:45
		ECTS: 4

PURPOSE:

The objective of this course is to provide fundamental knowledge of preparation, characterisation and application of conductive polymers. The students will be able to apply engineering skills for preparation and design of highly functionalized molecular structures and surfaces of conductive polymers.

THE CONTENTS OF THE COURSE:

Week 1:
Introduction. Dimensionality of carbon. Structure of electrically conductive polymers (Intrinsically Conducting Polymers). Comparison of conventional polymers and electrically conducting polymers. Comparison of ion-exchange polymers and electrically conducting polymers.

Week 2:
Electroactivity and electrical conductivity. The mechanism of electrical conductivity. Solitons, polarons and bipolarons. Doping of conducting polymers.

Week 3:
General remarks on conductivity. Temperature dependence of conductivity. Measurement of electrical conductivity. Hopping conductivity.

Week 4:
The mechanism of conducting polymers synthesis. Monomer oxidation and solvent influence.

Week 5:
Different methods of preparation. Chemical and Electrochemical Syntheses. Nucleation and polymer growth.

Week 6:
Exam

Week 7:
Chemical and physical properties of conducting polymers. Effects of monomer *functionalization*. Effects of doping process. Effects of film structure and morphology.

Week 8:
Spectroscopic investigation of conducting polymers. Electrochromism and application of conducting polymers in electrochromic devices.

Week 9:
Electrochemical investigation of conducting polymers.

Week 10:
Redox reaction of conducting polymers. Electron exchange reaction. Ion transport. Coupling of electron and ionic charge transport. Solvent transport and dynamics of polymer motion.

Week 11:
Catalysis. Conductometric, amperometric, voltammetric, potentiometric and gravimetric sensors. Application of conducting polymers in drug delivery systems.

Week 12:
Electroluminiscence. Organic light emitted diode based on conducting polymers. Photovoltaic cells. Photovoltaic cell based on conducting polymer.

Week 13:
Conducting polymers as active materials in electrochemical power sources. Conducting polymers as corrosion protection.

Week 14:
Nano-structurised conducting polymers. Composites of conducting polymers and nanostructurized materials. Composites of conducting polymers and conventional polymers.

Week 15:
Exam

Laboratory exercises
1. Chemical synthesis of polypyrrole.
2. Influence of solvent *nucleophilicity* on electropolymerisation process
2. Product distribution in electrochemical synthesis of polyaniline
3. Conducting polymers as active material in electrochemical power sources
2. Electrochromic properties of conducting polymers

GENERAL AND SPECIFIC COMPETENCE:

General competencies:
- Ability to design and conduct scientific experiment and data interpretation
- Ability to work in a team and development of good communications skills
- Developing of communication skills in written, oral and graphical forms

Specific competencies
- Ability to recognise scientific and technological roll and importance of electrically conducting polymers
- Applying of modern analytical and physico-chemical methods in development and application of conducting polymers
- Ability to understand the principles of conductivity in order to prepare and improve conducting polymer properties

KNOWLEDGE TESTING AND EVALUATION:

Two progress evaluations during the course.

Knowledge testing after the laboratory work.

Written exam.

Oral exam.

MONITORINGOF THE COURSE QUALITY AND SUCCESSFULNESS:

Student’s survey.

LITERATURE:

7. Conducting polymers- lectures at faculty web sites
8. S. Roth, "One-Dimensional Metals", VCH, Weinheim, 1971.
9. L. Alacer, "Conducting Polymers", D. Reidel Publishing Company, Dordrecht, 1987.
10. G. G. Wallace et. al. "Conductive Electroactive Polymers", CRC Press, 2009.
11. G. Inzelt, "Conducting Polymers: A New Era in Electrochemistry", Springer, 2009.
12. P. Chandrasekhar, "Conducting polymers: Fundamentals and Application", Kluwer Academic Publisher, London, 1999.

Course: ELASTOMERS		
Language: English		
Lecturer: Prof. Zlata Hrnjak – Murgić, PhD		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**0**	**0**
Seminar	**1**	**15**
		Overall: 45
		ECTS: 4

PURPOSE:

Introduction to natural and synthetic rubbers. Vulcanization of rubber. Understanding of natural and synthetic rubber with the basic characteristics and application of some rubber types. Design, processing and production of tires.

THE CONTENTS OF THE COURSE:

Lectures:

1. Vulcanization and vulcanization system.
2. Natural and synthetic rubber- characterization.
3. Natural rubber.
4. Polybutadiene and polyisoprene rubber.
5. Styrene – butadiene rubber. Silicone rubber.
6. Ethylene-propylene and ethylene-propylene-diene rubber.
7. 1st partial test
8. Polychloroprene rubber.
9. Chlorobutyl rubber.
10. Fluorine rubber.
11. Nitrile rubber.
12. Polysulfide rubber.
13. Product design. Rubber processing and production.
14. Degradation and regeneration of rubber.
15. 2nd partial test

Seminar:

- Making presentations and / or written seminar paper on a given topic

GENERAL AND SPECIFIC COMPETENCE:

The aim of this course is to introduce the students with certain types of rubber, their synthesis – various types of vulcanization and processing technology. Understanding the relationship structure – properties and their application in everyday life.

KNOWLEDGE TESTING AND EVALUATION:

Partial tests (2 times) (written) or exam (written and/or oral)

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

University of Zagreb student survey

LITERATURE:

8. H. Mark, N. Bikales, C. Overberger, G. Menges, Encyclopedia of Polymer Science and Engineering, John Wiley & Sons, New York, **1-17**, (1985-1989).
9. I. Franta, Elastomers and Rubber Compounding Materials, Elsevier, New York, (1989).
10. Z. Janović and D. Štefanović, Kaučuk i guma in H. Požar, Tehnička enciklopedija, Jug. Leksikografski zavod, **6**, (1979) 742-758.
11. Joel R. Fried, Polymer Science and Technology, Prentice Hall Professional, USA, 2003.

Course: Adhesion and adhesive products		
Language: English		
Lecturer: Prof. Mirela Leskovac		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**0**	**0**
Seminar	**1**	**15**
		Overall: 45
		ECTS: 4

PURPOSE:

To introduce students to the functional characteristics of products which are used as adhesives and sealants in understanding their structure and properties, quality factors and their target applications in bonding technologies. The emphasis is on the effects of surface phenomena, environmental influences and stresses in the application. Within Analysis of samples - a case study in a seminar in selected experimental exercises, students develop specific knowledge and skills that enable them to assess the quality and characteristics of adhesive materials, as well as their choice for a particular purpose.

THE CONTENTS OF THE COURSE:

L-Lectures (1-15); LE-Laboratory exercises; S- Seminar (1);

L (1-3) Application of surface science. Definition and application of following terms: surface tension, surface and interfacial energy, the thermodynamic work of adhesion, wetting, spreading and debonding. Inhomogeneity of surface and measurements.

L (4-6) Practical adhesion. The application of mechanisms and theories in analyzing results of the adhesion bonding. Mechanical, diffusion, adsorption, chemical, electrostatic theory in practice. Criteria for achieving quality adhesion bonds.

LE - Determination of parameters of adhesion

L (7-9) Characterization of surfaces. Analysis of the specificity of polymer surfaces. Application of thermodynamics and solubility parameters in assessing the adhesion properties of the surface. The effects of surface modification. Application of the method for the characterization of surfaces.

L (10-15) The adhesive products. The application of scientific methodology of product engineering in the analysis pyramid of the product. Types of adhesives and sealants. The specifics of their application. Characteristics of the structure and properties of the matrix and the impact on the formulation and implementation of quality factors. Examples of adhesives and sealants given purpose.
Structural and non-structural adhesives. Epoxies, urethanes, neoprene, cyanoacrylates as base adhesives. Acrylic, Bituminous, polysulfide, silicone, polyether and polyurethane sealants. The advanced adhesive products based on nanotechnology. A new generation

of silane-terminated organic seal. Analysis of the practical implementation of Adhesion bonding. The elements for optimal selection of adhesives and sealants.
LE - testing of adhesive compound
S

GENERAL AND SPECIFIC COMPETENCE:

General competencies of students complement with application of basic knowledge of surface phenomena, which are essential for proper adhesion at the interface between two materials in the application process of bonding, as well as designing new products for the market.
Specific competencies are related to the possibility of appropriate modifications of bonding process by modification and activation of surfaces in industrial applications, as well as the selection of appropriate product for a given application.

KNOWLEDGE TESTING AND EVALUATION:

Partial exam, written exam

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student questionnaire.

LITERATURE:

1. V. Kovačević, Adhezija i adhezijski proizvodi, interna skripta, 2009.
2. A.J. Kinloch, Adhesion and Adhesives; Science and Technology, Chapman & Hall, London, UK, 1995.
3. K.L. Mittal, Adhesion Measurement of Films and Coatings, VSP, Utrecht, 1995.
4. A. Pizzi, K.L. Mittal, Handbook of Adhesive Technology, 2nd Ed., Marcel Dekker, Inc., New York, 2003.
5. K.L. Mittal, A. Pizzi, Adhesion Promotion Techniques: Technological Applications, Marcel Dekker, Inc., New York, 2004.
6. E.M. Petrie, Handbook of Adhesives and Sealants, Mc-Graw-Hill, New York, 2000.

Course: CEMENT COMPOSITE ADMIXTURES		
Language: English		
Lecturer: Prof. Nevenka Vrbos, Ph. D.		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**graduate2.(1.) th term**
Laboratory	**1**	**Graduate2.(1.) th term**
Seminar		
		Overall :2+1
		ECTS: 4

PURPOSE :

To show the variety of cement materials admixtures. To both provide a list of most frequently used admixtures and give a closer look at the mechanism of their effect. To show the influence of certain admixtures on the hydration of cement and cement minerals.

THE CONTENTS OF THE COURSE:

Classification of admixtures used in construction. Superplasticizers. Chemical types of superplasticizers. Superplasticizing effect and its mechanism. The influence of superplasticizers on cement hydration. The use of superplasticizers. Plasticizers. The influence of plasticizers on the hydration of C_3A. The application of plasticizers. Accelerators. Chloride accelerators. Non-chloride accelerators. Lithium salts as the accelerators of reaction. Retarders. Chemical types of retarders. The influence of retarders on the hydration of cement minerals. The application of retarders .Air entraining admixtures. The effect of concrete consistency on air entrainment. Anti-freezing admixtures. Silica fume. Sources of silica fume emission. The effect of silica fume on the hydration of portland cement. Norms and specifications used for silica fume. Fly ashes. Sources and characteristics of fly ashes. The influence of fly ashes in the hydration of portland cement.

GENERAL AND SPECIFIC COMPETENCE:

Point out the structure, properties and use of additives used. Acquire knowledge of all additives and the required criteria for use.

KNOWLEDGE TESTING AND EVALUATION:

Knowledge will be monitored conversation during lectures and tutorials.

A written exam will be coupled with the possibility of student essays.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student survey

LITERATURE:

1.Đureković,Cement,cementni kompoziti i dodaci za beton,Školska knjiga,Zagreb,1996

2.M.R.Rixom i N..Mailvaganam,Chemical Admixtures for Concrete,London,New York,E.and F.N.Spon,1986

X-ray diffraction in materials engineering

1. The discovery of X-rays. Hystorical development of X-ray diffraction methods.
2. Radiation safety for users of X-ray diffraction. Important radiation measurement units. Biological effects of radiation exposure. Principles of radiation protection.
3. The concept of structure. Crystalline and amorphous state. Monocrystal and polycrystalline material. Factors defining crystal structure. Structure types.
4. Crystallography. Crystal systems. Symmetry operations. Elements of simmetry. Point group.
5. Bravais lattices, Symmetry operations with translation,. Space groups. Crystal structure description. Miller indices.
6. Generation of X-rays. Properties of X-rays. X-ray spectrum, continuous and characteristic radiation.
7. Radiation interactions with matter. Absorption, diffraction. Laue equations, Bragg equation.
L1. The use of X-ray diffraction equipment.
8. Factors affecting the intensity of X-rays: Atomic scattering factor, structure factor. Systematic absences. Absorption coefficient. Lorentz-polarization factor. Temperature factor. Multiplicity.
L2. X-ray qualitative analysis. The use of Hanawalt system.
I. partial exam
9. Selected X-ray diffraction methods. Powder X-ray diffraction methods. Diffractometer method. The geometry of diffractometer. Optics. Monochromators. Detectors. Sample holders. Sample preparation.
L3. X-ray qualitative analysis, the use of computer software.
10. X-ray qualitative analysis, ICDD database. Qualitative analysis of complex systems. Practical advices for successful analysis. Detection limit. Most common errors. Connected to radiation, geometry, sample position and sample itself.
L4. X-ray quantitative analysis.
11. X-ray quantitative analysis: external and internal standard methods, Method of standard additions, reference intensity ratio methods. The determination of unit cell parameters. Monitoring of solid solution composition changes. Dynamic X-ray diffraction.
L5. refinement of unit cell parameters.
12. *Crystallite size and micro strain measurements.* Scherrerova equation. The determination of diffraction peaks broadness. Microstrain and macrostrain. Stokes and Wilson equation. Williamson-Hall analysis.
L6. The determination of crystallite size.
13. Basics of crystal structure solving**.** Rietveld refinement. Analytical equation for approximate description of diffractogram. Parameter initialization and analysis path. Quantitative indicators of analysis quality.
II. partial exam

Course: Introduction to nanotechnology		
Language: English		
Lecturer: Prof. Sanja Lučić Blagojević; Prof. Stanislav Kurajica		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**0**	**0**
Seminar	**2**	**30**
		Overall:60
		ECTS: 4

PURPOSE:

Accepting of the basic terms of nanotechnology. Acquiring knowledge on properties of nanomaterials. Getting acquainted with methods of preparation and characterization of nanomaterials. Acquaint with the most important kinds of nanomaterials and its applications.

THE CONTENTS OF THE COURSE:

1. Concepts of nanoscience and nanotechnology, molecular nanotechnology. History of nanotechnology, Gordon E, Moore, Richard P. Feynman, Eric K. Drexler, R. Kurzweil. Phenomena on nano-level: quantum effects, surface to volume ratio, the dominance of electromagnetic forces.

2. Properties of nanomaterials: physical, mechanical, chemical, optical, electrical, magnetic. Tunelling effect, quantum confinement, quantum dots, nanostructure, magical numbers. Hall-Petch effect, superparamagnetism, giant magnetoresistance, lotos effect.

Laboratory exercise 1. The determination of crystallite size using Scherrer method.

3. Characterization of nanomaterials. Scanning electron microscope, transmission electron microscope, scanning tunneling microscope, atomic force microscope.

Laboratory exercise 2. Synthesis of silver nano-particles.

4. Nano-manufacturing: top-down approach: photolitography, soft litography, microcontact printing, nano-print litography, dip-pen nanolitografy, high-energy milling, PVD, CVD.

Laboratory exercise 3. The preparation of superparamagnetic nano-particles.

5. Nano-manufacturing: bottom-up approach: precipitation, crystallization, colloids, colloid stabilization, solid suspensions, self-assembly, micelles, thin films, self-assembled monolayers, dendrimers, super-latices, sol-gel method. Nanomanipulation, contact and contactless nanomanipulation. The aims for nanomanipulation.

Laboratory exercise 4. Sol-gel synthesis of SiO_2 nanoparticles.

6. Trends in nanotechnology: Nanomaterials (nano-structured materials, smart materials, ageless materials), nanoproducts (electronics, medicine, environment, industrial technology). Nanorobots. The applicative potential of nanomaterials. Sociological

acceptance of nanomaterials. Riscs of nanotechnology Future of nanotechnology.

7. I. Partial exam

8. Carbon nanostructures; Fullerene – synthesis, properties, reactivity, potential application; Carbon nanotubes – molecular and supramolecular structure, intrinsic properties, synthesis, purification, modification, application

9. Nanoscale electronic, Development of microelectronic devices and technology, Structure and operation of MOF transistor; Transistor scaling, Nanoscaled MOFSET transistors;

10. Molecular electronic – possibilities, preparation and investigation of molecular devices; Molecular switches, transistors and similar devices; Electronic with DNA molecules; Single electron electronic devices

11. Nanocomposites – preparation, structure and properties

12.-13. Nanobiotechnology – biomimetic nanostructures, interface with biologic structure and functions: Biomolecular motors – MEMS and biomolecular motors. Operations and functions of motor proteins; Biotechnology of motor proteins; Science and engineering of molecular motors, Engineered devices; Molecular motors in technological application

14. II. Partial exam

GENERAL AND SPECIFIC COMPETENCE:

Knowledge of basic concepts of nanoscience and nanotechnology. Noticing the diversity properties of nano-materials and macro-materials and understand the reasons of these differences. Knowledge of ways of getting nanomaterials on the principle top-down and bottom-up. Knowledge of basic methods of characterization of nanomaterials. Understanding the trends in nanotechnology.

KNOWLEDGE TESTING AND EVALUATION:

Partial exams, written/oral exam

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student questionnarie

LITERATURE:

1. Di Ventra M., Evoy S., Heflin R.J., Introduction to Nanoscale Science and Technology, Springer, 2004.
2. Owens P.,Introduction to Nanotechnology, John Wiley & Sons, 2003.
3. Wilson M., Kannangara K., Smith G., Simons M., Raguse B., Nanotechnology, basic science and emerging technologies, Chapman &Hall, 2002.

Course: Material engineering laboratory

Language: English

Lecturer: Prof. Sanja Lučić Blagojević; Prof. Mirela Leskovac;
Prof. Emi Govorčin Bajsić

TEACHING	WEEKLY	SEMESTER
Lectures	**0**	**0**
Laboratory	**0**	**0**
Seminar	**4**	**60**
		Overall:60
		ECTS: 8

PURPOSE:

To acquire knowledge, to develop methodologies and approaches for independent scientific work in the field of chemistry and engineering of materials. The objective can be achieved by acquiring competence in the analysis and synthesis of previous literature findings, independent experimental work and analysis of results.

THE CONTENTS OF THE COURSE:

Week 1: Introducing students to the objectives and learning outcomes of the course, the criteria of evaluation activities and testing criteria. Selection of topics by students.

Weeks 2-4: Analysis and synthesis of the literature findings related to the topic and tasks; Understanding the advantages and disadvantages of the methods for materials preparation; introduction to methodology and data analyses for individual techniques of physical and or chemical analysis.

Week 5: Oral presentation of defined goals, literature knowledge and flow diagram for a given research issues to students and teachers.

Week 6-14: Independent implementation of selected elements of engineering materials (preparation, characterization, application) depending on the given topic. The presentation of the work and the results of their own task in writing.

Week 15: Presentation of tasks, research results and conclusions orally to students and teachers.

GENERAL AND SPECIFIC COMPETENCE:

General competencies:
- Gaining experience in independent work in a safe manner in the chemical and / or physical laboratory.
- Presentation of literature knowledge, their own results and conclusions in oral and written form.

Specific competencies:
- The application of scientific principles of chemistry and material engineering in the given topics.

- Understanding and application dependencies between elements of materials engineering (method of preparation, characterization, properties, applications) for different types of materials (ceramic, polymer, metal). - Analysis of materials using various techniques and methods, depending on the given topic. - Critically analysis of own results, connection of these results with current literature findings and draw conclusions about obtained results.
KNOWLEDGE TESTING AND EVALUATION: Continuous monitoring and evaluation.
MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS: Student questionnaire.
LITERATURE: General and specific references depending on the given topic

Course: Quality management, Material Science and Engineering
(2nd year, 3rd semester, mag. ing. cheming.)

Language: English

Lecturer: Associated professor Danijela Ašperger, Ph.D.

TEACHING	WEEKLY	SEMESTER
Lectures	**2**	**15**
Laboratory	**2**	**15**
Seminar	**1**	**15**
		Overall: 75
		ECTS: 6

PURPOSE:
Introducing students to the establishment, development and implementation of quality systems and quality monitoring processes, products and services. The above skills are a prerequisite for participation in the European integration process of exchanging goods, services and information.

THE CONTENTS OF THE COURSE:

Lectures and seminars:

1. Introduction. The quality system. Planning, implementing and documenting quality assurance programs.
2. The elements of the quality system. Quality assurance of the production process. Ensuring the quality of the measuring process.
3. The importance of appropriate measurement process to ensure the quality of processes and products.
(Seminar: computational tasks.)
4. Planning and standardization of the measurement system.
5. Planning and optimization experiments.
6. Sources of errors and their removal.
(Seminar: computational tasks.)
7. The impact of measurement uncertainty on the result of the decision.
(Seminar: computational tasks.)
8. The first partial test.
9. Quality Control. Validation.
(Seminar: computational tasks.)
10. Internal and external quality assessments. Collaborative studies. Reference materials.
11. An independent assessment of the quality system. Certification and accreditation.
12. Improving Quality: diagrams by Ishikawa, Pareto diagram, the method of process analysis.
13. Project management - goals, phases, processes, planning, quality, time and cost. Cost-benefit analysis. Standards and standardization.
14. The second partial test.
15. Seminars students on a given topic.

Laboratory exercises:
(block courses in six periods by 5 hours)
1. Determining the composition of copper alloys classical analysis - determining outliers Q-test.
2. The validation of thin layer chromatography method for determination of pesticides in soil.
3. Comparison of extraction methods for the determination of polyphenols in chocolate - determining the impact of interference from the sample to the chromatographic determination after different methods of extraction.
4. Determination of antibiotics in water by SPE-HPLC-DAD method - the qualitative and quantitative determination of an analyte, and determining the effectiveness of the solid phase extraction.

GENERAL AND SPECIFIC COMPETENCE:
Students gain basic knowledge for establishing quality in the analytical laboratory, as the quality of work in the analytical laboratory to ensure, control and evaluate and apply them to real samples from the environment, in food analysis or other samples (alloys, ores) in accordance with good laboratory practices.

KNOWLEDGE TESTING AND EVALUATION:
Written and oral examination. The possibility of release written part of the exam if you collect enough points.
The oral part of the exam with the teacher.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:
Student questionnaire.

LITERATURE:

1. LECTURES:
1.) M. Kaštelan-Macan, Kemijska analiza u sustavu kvalitete, Školska knjiga Zagreb, 2003.
2.) Analitika okoliša, ur. M. Kaštelan-Macan i M. Petrović, HINUS i Fakultet kemijskog inženjerstva i tehnologije, Zagreb, 2013.

2. SEMINAR:
Z. Šoljić, Računanje u kvantitativnoj kemijskoj analizi, Sveučilište u Zagrebu, Zagreb 1998.

3. LABORATORY EXERCISE:
D. Ašperger, Interna skripta za laboratorijske vježbe iz kolegija Upravljanje kvalitetom, ZAK, FKIT, Zagreb, 2009.

ADDITIONAL LITERATURE:
1.) J. M. Miller, Chromatography-Concepts and Contrasts, Wiley-Interscience, New Jersey, 2005.
2.) D. A. Skoog, D. M. West, F. J. Holler, Osnove analitičke kemije, Školska knjiga Zagreb, 1999.
3.) K. Eckschlager, K. Danzer, Information Theory in Analytical Chemistry, John Wiley&Sons, Inc., New York 1998.
4.) F. M. Garfield, Quality Assurance Principles for Analytical Laboratories, AOAC, 1991.

Course: Polymer nanocomposites

Language: English

Lecturer: Prof. Sanja Lučić Blagojević

TEACHING	WEEKLY	SEMESTER
Lectures	**2**	**30**
Laboratory	**0**	**0**
Seminar	**1**	**15**
		Overall: 45
		ECTS: 4

PURPOSE:

To introduce students with access of design of nanocomposite polymer materials aiming to achieve specific properties. The objective can be achieved by integrating knowledge from the field of polymer materials, inorganic materials, and knowledge about the modelling of the interface polymer / filler.

THE CONTENTS OF THE COURSE:

L1 - Polymeric materials. The importance and application of polymeric materials. Classification of polymer materials by origin, by application properties, according to the type of repeating units, according to the forms of macromolecules. Mechanisms of polymerization: step, chain; homogeneous and heterogeneous processes of polymerization. The structure of polymers: configuration and conformation of macromolecules. Super-molecular structures. Physical properties of polymers. Additives to polymer materials. Fillers as modifiers of properties.

L2 - Differences between micro and nanocomposites. Polymer Composites. Interphase polymer - filler: mechanisms of adhesion, the application of adsorption theory. Thermodynamics of interfacial free energy, coefficient of wetting, thermodynamic work of adhesion. Chemisorption theory. Differences between nanocomposites and microcomposites: filler particle size, size of the interface, morphology, fraction of matrix in the interphase layer.

L3-5 The types of nanofillers. *Carbon nanotubes*: molecular and supramolekulna structure, properties (mechanical properties, electrical properties). Processing of nanotubes: laser ablation, arc discharge, chemical vapor deposition. Composition and purification of the reaction products. Surface modification (covalent and non-covalent)

The layered nanofillers: types, structure, organic modification of layered nano-filler. *Equi-axed nanofillers*: types, production, surface modification.

Quantum dots: types, structure, quantum effects, properties. Surface modification of quantum dots: with amphiphilic polymers, multidentate polymeric ligands, polymers functionalized at the ends of the chain, quantum dots encapsulated by dendrimers.

1st partial exam

L7-9 Preparation of polymer nanocomposites. The distribution and the dispersibility of fillers in the polymer matrix. *Preparation process for composites with carbon*

nanotubes: preparation of the solution, stirring the mass of the polymer, the mixing in the melt, in situ polymerization.
Preparation of nanocomposites with layered nano-fillers: intercalated and exfoliated morphology, instrumental techniques for morphology investigation. Methodology and thermodynamics of individual processes: intercalation of polymer or prepolymer, in situ intercalation polymerization, melt intercalation. The impact of factors on the morphology of the melt intercalation process. The degradation of the system during the preparation of the melt intercalation.
Preparation of polymer nanocomposites with equi-axed nano-fillers. The process for preparing the melt and solution, in situ polymerization of the polymer, the in situ polymerization of the inorganic phase is formed.
Preparation of nanocomposite system quantum dot / polymer. Quantum dots in polymer colloids - a methodology for preparing nanocomposites with different methods, advantages and disadvantages of different methods of preparation. Systems of layer-by-layer quantum dot / polymer. Controlled binding of polymer layers and quantum dots. Quantum dots in polymers bulk and thin polymer films.

L10-11 Properties and application of polymer nanocomposites. Mechanical properties: the influence of types of nano-filler, filler particle size and thermodynamics of the polymer / filler morphology, failure mechanisms and features of the mechanical behavior (modulus, tensile strength, toughness). Effect of nanofiller on the permeability of gases and liquids: the concept of tortuous diffusion. Dimensional stability of nanocomposites. The thermal stability of the nanocomposites. Effect of nanofillers on flammability of polymers. Electrical properties. Optical and optoelectronic properties.

L12 2nd partial exam

L13-15 Student seminars

GENERAL AND SPECIFIC COMPETENCE:

The course develops the general students' competence of analysis and synthesis of scientific knowledge and presentation in oral form.

Specific competencies courses include connecting knowledge engineering polymer materials and surface and interfacial engineering in multiphase polymer systems, broadening and deepening the knowledge of the structure, properties, production and application of polymer nanocomposites as advanced materials, and knowledge about the selection of techniques and methods for the characterization of multiphase systems and quality control of the final products.

KNOWLEDGE TESTING AND EVALUATION:

Partial exams, writing and oral exam

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student questionnaire.

LITERATURE:

1. P. M. Ajayan, L. S. Schadler, P. V. Braun, Nanocomposite Science and Technology, Wiley – VCH, 2003.
2. T. J. Pinnavaia, G. W. Beall, Polymer-Clay Nanocomposites, John Wiley and Sons Inc., 2001.
3. A. I. Nakatani, R. P. Hjelm, M. Gerspacher, R. Krishnamoorti, Filled and Nanocomposite Polymer Materials, Vol.661, Materials Research Society, 2001.
4. R.Vaia, R. Krishnamoorti, Polymer nanocomposites: Synthesis, Characterization and Modeling, American Chemical Society, 2001.
5. Y. S. Lipatov, Polymer Reinforcement, Chem. Tec. Publishing, Ontario, 1995.

Course:	**Additives for polymer materials (optional)** Material Science and Engineering, graduation; 1st and 2nd year

Language: English

Lecturer: Mirela Leskovac

TEACHING	WEEKLY	SEMESTER
Lectures	**2**	**30**
Laboratory	**1**	**15**
Seminar	**-**	**-**
		Overall: 45
		ECTS: 4

PURPOSE:

Familiarizing with the most important additives which are used for modification, improvement of properties and resistance of polymer materials and their products, focused on mechanisms of their action and application.

THE CONTENTS OF THE COURSE:

L-1 An introduction to polymer additives. Classification of additives for polymer materials and products, principles of their action, properties and application; ecological and economical impacts of polymer additives.
L-2 Modifiers of physical properties of polymer materials; principles of their action, classification, properties and applications. The polymer additives efficiency.
L-3 Improvement/ Modification of mechanical properties. Impact modifiers: toughness and macromolecular modifiers. Additives for improvement of strength, processibility and stability: fillers, reinforcing agents and coupling agents.
L-4 Blowing agents; chemical and physical blowing agents; characteristics and factors acting on blowing.
L-5 Plasticizers: Solubility parameter, theory of plasticization, primary and secondary plasticizers. Classification of plasticizers. Plasticizer efficiency.
L-6 Modifiers of optical properties: dyes, pigments and optical brighteners. Classification, properties and application. Criteria for selection of pigments.
L-7 Modifiers of surface properties. Lubricants: reducing of friction, surface abrasion and adhesion. The effect of lubrication on the polymer processing.
L-8 Conductivity: antistatic and conductive additives, action mechanism, classification, properties and application.
L-9 Additives that have a protecting effect against polymer aging and degradation; action mechanism, classification, properties and application.
L-10 Effects of chemically and physically active media, effect of ionizing radiations, mechanical and thermal degradation.
L-11 Heat stabilizers; the influence of heat stabilizers. Thermo-oxidative degradation: action mechanism of antioxidants.
L-12 Photo-oxidative degradation: action mechanism of UV stabilizers, classification and application.
L-13 Flammability: burning mechanism of polymers, flame retardants; action mechanism of retardants, classification, properties and applications.

L-14 Microbiological degradation: action mechanism of biocides; properties and application.
L-15 Methods used to incorporate additives into polymer matrices. Ecological aspects of application of additives for polymer materials and their products. Technical trends and new market requests.

Laboratory exercises:

I. PROPERTIES OF POLYMER ADDITIVES

LE-1) Surface phenomena and surface tension measurement by pendant drop method.

II. OXIDATIVE STABILITY OF POLYMER MATERIALS

LE-2) Influence of additives on the oxidative stability of materials; determination of oxidation induction time, OIT

LE-3) Influence of additives on the oxidative stability of materials; determination of oxidation induction temperature, OIT*

LE-4) Influence of additives on the thermal stability of polymer materials.
LE-5) Polymer flammability - Limited oxygen index (LOI)

III. PRINCIPLES OF POLYMER PLASTICIZATION

LE-6) Influence of plasticizers on the polymer material properties.
LE-7) Evaluation of plasticizers efficiency.
LE-8) The influence of plasticizers on the polymer surface properties (study of plasticizers migration).

L-Lectures, **LE**-Laboratory exercises

GENERAL AND SPECIFIC COMPETENCE:

Acquiring knowledge required to obtain satisfactory properties of polymeric materials and quality. Knowledge relevant to the selection of additives and features crucial for ensuring the quality and stability of engineering polymers depending on the specific requirements of the application.
Specific competencies include training of future experts to apply the acquired knowledge in the production process and quality control.

KNOWLEDGE TESTING AND EVALUATION:

Partial exams; written / oral exam.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student questionnaire.

LITERATURE:

1. M. Leskovac, *Dodatci za polimerne materijale i proizvode*, Interna skripta, 2008.
2. Z. Janović, Polimerizacije i polimeri, Hrvatsko društvo kemijskih inženjera i tehnologa, 1997.
3. L. H. Sperling, Introduction to Physical Polymer Science, Wiley Interscience, New Yersey, 2006.

ADDITIONAL LITERATURE:

4. Jan C.J. Bart, Additives in polymers (Industrial Analysis and Applications), John Wiley & Sons Ltd, England 2005
5. J. T. Lutz, R.F. Grossman, Polymer Modifiers and Additives, Marcel Dekker, 2001.
6. J. Štepek, H. Daoust, Additives for Plastics, Springer-Verlag, New York, 1983.

Course: ELASTOMERS		
Language: English		
Lecturer: Prof. Zlata Hrnjak – Murgić, PhD		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**0**	**0**
Seminar	**1**	**15**
		Overall: 45
		ECTS: 4

PURPOSE:

Introduction to natural and synthetic rubbers. Vulcanization of rubber. Understanding of natural and synthetic rubber with the basic characteristics and application of some rubber types. Design, processing and production of tires.

THE CONTENTS OF THE COURSE:

Lectures:

16. Vulcanization and vulcanization system.
17. Natural and synthetic rubber- characterization.
18. Natural rubber.
19. Polybutadiene and polyisoprene rubber.
20. Styrene – butadiene rubber. Silicone rubber.
21. Ethylene-propylene and ethylene-propylene-diene rubber.
22. 1st partial test
23. Polychloroprene rubber.
24. Chlorobutyl rubber.
25. Fluorine rubber.
26. Nitrile rubber.
27. Polysulfide rubber.
28. Product design. Rubber processing and production.
29. Degradation and regeneration of rubber.
30. 2nd partial test

Seminar:

- Making presentations and / or written seminar paper on a given topic

GENERAL AND SPECIFIC COMPETENCE:

The aim of this course is to introduce the students with certain types of rubber, their synthesis – various types of vulcanization and processing technology. Understanding the relationship structure – properties and their application in everyday life.

KNOWLEDGE TESTING AND EVALUATION:

Partial tests (2 times) (written) or exam (written and/or oral)

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

University of Zagreb student survey

LITERATURE:

12. H. Mark, N. Bikales, C. Overberger, G. Menges, Encyclopedia of Polymer Science and Engineering, John Wiley & Sons, New York, **1-17**, (1985-1989).
13. I. Franta, Elastomers and Rubber Compounding Materials, Elsevier, New York, (1989).
14. Z. Janović and D. Štefanović, Kaučuk i guma in H. Požar, Tehnička enciklopedija, Jug. Leksikografski zavod, **6**, (1979) 742-758.
15. Joel R. Fried, Polymer Science and Technology, Prentice Hall Professional, USA, 2003.

Course: CEMENT COMPOSITE ADMIXTURES		
Language: English		
Lecturer: Prof. Nevenka Vrbos,Ph.D.		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**graduate2.(1.) th term**
Laboratory	**1**	**Graduate2.(1.) th term**
Seminar		
		Overall :2+1
		ECTS: 4

PURPOSE :

To show the variety of cement materials admixtures. To both provide a list of most frequently used admixtures and give a closer look at the mechanism of their effect. To show the influence of certain admixtures on the hydration of cement and cement minerals.

THE CONTENTS OF THE COURSE:

Classification of admixtures used in construction. Superplasticizers. Chemical types of superplasticizers. Superplasticizing effect and its mechanism. The influence of superplasticizers on cement hydration. The use of superplasticizers. Plasticizers. The influence of plasticizers on the hydration of C_3A. The application of plasticizers. Accelerators. Chloride accelerators. Non-chloride accelerators. Lithium salts as the accelerators of reaction. Retarders. Chemical types of retarders. The influence of retarders on the hydration of cement minerals. The application of retarders .Air entraining admixtures. The effect of concrete consistency on air entrainment. Anti-freezing admixtures. Silica fume. Sources of silica fume emission. The effect of silica fume on the hydration of portland cement. Norms and specifications used for silica fume. Fly ashes. Sources and characteristics of fly ashes. The influence of fly ashes in the hydration of portland cement.

GENERAL AND SPECIFIC COMPETENCE:

Point out the structure, properties and use of additives used. Acquire knowledge of all additives and the required criteria for use.

KNOWLEDGE TESTING AND EVALUATION:

Knowledge will be monitored conversation during lectures and tutorials.

A written exam will be coupled with the possibility of student essays.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student survey

LITERATURE:

1.Đureković,Cement,cementni kompoziti i dodaci za beton,Školska knjiga,Zagreb,1996

2.M.R.Rixom i N..Mailvaganam,Chemical Admixtures for Concrete,London,New York,E.and F.N.Spon,1986

X-ray diffraction in materials engineering

1. The discovery of X-rays. Hystorical development of X-ray diffraction methods.
2. Radiation safety for users of X-ray diffraction. Important radiation measurement units. Biological effects of radiation exposure. Principles of radiation protection.
3. The concept of structure. Crystalline and amorphous state. Monocrystal and polycrystalline material. Factors defining crystal structure. Structure types.
4. Crystallography. Crystal systems. Symmetry operations. Elements of simmetry. Point group.
5. Bravais lattices, Symmetry operations with translation,. Space groups. Crystal structure description. Miller indices.
6. Generation of X-rays. Properties of X-rays. X-ray spectrum, continuous and characteristic radiation.
7. Radiation interactions with matter. Absorption, diffraction. Laue equations, Bragg equation.
L1. The use of X-ray diffraction equipment.
8. Factors affecting the intensity of X-rays: Atomic scattering factor, structure factor. Systematic absences. Absorption coefficient. Lorentz-polarization factor. Temperature factor. Multiplicity.
L2. X-ray qualitative analysis. The use of Hanawalt system.
I. partial exam
9. Selected X-ray diffraction methods. Powder X-ray diffraction methods. Diffractometer method. The geometry of diffractometer. Optics. Monochromators. Detectors. Sample holders. Sample preparation.
L3. X-ray qualitative analysis, the use of computer software.
10. X-ray qualitative analysis, ICDD database. Qualitative analysis of complex systems. Practical advices for successful analysis. Detection limit. Most common errors. Connected to radiation, geometry, sample position and sample itself.
L4. X-ray quantitative analysis.
11. X-ray quantitative analysis: external and internal standard methods, Method of standard additions, reference intensity ratio methods. The determination of unit cell parameters. Monitoring of solid solution composition changes. Dynamic X-ray diffraction.
L5. refinement of unit cell parameters.
12. *Crystallite size and micro strain measurements.* Scherrerova equation. The determination of diffraction peaks broadness. Microstrain and macrostrain. Stokes and Wilson equation. Williamson-Hall analysis.
L6. The determination of crystallite size.
13. Basics of crystal structure solving. Rietveld refinement. Analytical equation for approximate description of diffractogram. Parameter initialization and analysis path. Quantitative indicators of analysis quality.
II. partial exam

Course: PACKAGING POLYMER MATERIALS		
Language: English		
Lecturer: **Prof. Zlata Hrnjak-Murgić, PhD**		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**0**	**0**
Seminar	**1**	**15**
		Overall:45
		ECTS: 4

PURPOSE:

Introducing students to the packaging polymer materials, their role and their importance in the areas of packaging and their applications.

THE CONTENTS OF THE COURSE:

1st week: Introduction. Classification of packaging, role of the packaging

2nd week: Properties of packaged goods, properties of packaging materials

3rd week: Labelling of packaging and consumption

4th week: Properties and characteristics of the packaging material

5th week: Barrier properties, biopolymers

6th week: Polymers for packaging materials

7th week: 1st partial test

8th week: Biodegradable polymers.

9th week: Layered packaging materials

10th week: Technological of processing

11th week: Packaging materials and waste - characterization

12th week: Management of packaging materials

13th week: Recycling of packaging materials.

14th week: 2nd partial test

Seminar: Making presentations and / or written seminar paper on a given topic

GENERAL AND SPECIFIC COMPETENCE:

The students will learn about polymer packaging materials and become competent to work in the field. They will gain an insight into the field of polymer waste management.

Specific competencies: students will gain knowledge and competence about the

properties and importance of packaging polymer materials, acquire knowledge for their quality control.
KNOWLEDGE TESTING AND EVALUATION: Partial tests (2 times) (written) or exam (written and/or oral)
MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS: University of Zagreb student survey
LITERATURE: 1. O.G. Piringer, A. L. Baner, Plastic Packaging Materials for Food: Barrier Function, Mass Transport, Quality Assurance and Legislation, J. Wiley & Sons, N. York, 1999 2. K. Galić, N. Ciković, K. Berkocić, Analiza ambalažnog materijala (Analysis of packaging materials), Zagreb, 2000 3. A. L. Andrady, «Plastics and the Environment», J. Wiley & Sons, Hoboken, New Jersey, 2003 4. C. D. Marotta, Packaging Materials, in H.F. Mark, N. M. Bikales, C.G. Overberger i G. Menges, Encyclopaedia of Polymer Science and Engineering, J. Wiley & Sons, N. York, 1987, Vol. 10, p.684. 5. Science Direct, Web of Science

Course: POLYMER SCIENCE AND TECHNOLOGY		
Language: English		
Lecturer: Prof. Zlata Hrnjak – Murgić, PhD		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**1**	**15**
Seminar	**1**	**15**
		Overall: 60
		ECTS: 4

PURPOSE:

The purpose of the course is to introduce students to polymer science and technology. The knowledge includes polymer processes; bulk, solvent, suspension and emulsion polymerization. Basis of polymer thermodynamics of solubility, degradation, compatibility. Polymers waste management, methods for reducing the volume of plastic waste.

THE CONTENTS OF THE COURSE:

31. Introduction to polymer science. Classification of polymers. Nomenclature of polymers.
32. Chain growth polymerization. Step growth polymerization. Catalysts.
33. Ionic polymerization: anionic and cationic polymerization. Living polymers.
34. Reaction of copolymerization. Lewis-Mayo equation. Typical copolymerization diagrams. Q-e scheme.
35. Ring-opening polymerization.
36. Polymer processes: Bulk polymerization and polymerization in solution. Suspension polymerization. Emulsion polymerization.
37. Reactors in polymer chemistry. Reactions of crosslinking.
38. 1st partial test
39. Polymer Materials; structure –properties relationships
40. Technology of plastics processing
41. Polymer degradation and stability (thermal degradation, oxidative and UV stability)
42. Thermodynamics of solubility, Compatibility of polymers, blends and composites
43. Biopolymers
44. Polymer Waste Management and Sustainable development
45. 2nd partial test

Laboratory:

10. Suspension polymerization of poly(vinyl-acetate)
11. Determination of molecular mass (viscosity)
12. Swelling of rubber
13. Identification of polymers: FTIR spectrophotmetry, TGA, DSC, DMA

5 Extrusion

Seminar:

- Making presentations and / or written seminar paper on a given topic

GENERAL AND SPECIFIC COMPETENCE:

General competencies of students - 1st understanding polymer systems during synthesis, 2nd competence to understanding and analyzing production processes of polymers, 3rd understanding of the basic knowledge of synthesis, structure and properties, and the competence to identify and solve problems in the field of waste plastics.

Specific competencies ofstudents- 1st gaining knowledge about the synthesis of polymeric materials, 2nd understanding the mechanisms of catalytic polymerization process, 3rd knowledge and competence of understanding the basic elements of chemistry and engineering materials related to the chemical composition, structure, manufacturing, properties and applications, 4th knowledge about the basic principles of environmental protection and polymers waste management, 5th ability to independently present the lab results in written and oral form.

KNOWLEDGE TESTING AND EVALUATION:

Partial tests (2 times) (written) or exam (written and/or oral)

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

University of Zagreb student survey

LITERATURE:

16. H. Mark, N. Bikales, C. Overberger, G. Menges, Encyclopaedia of Polymer Science and Engineering, John Wiley & Sons, New York, Vol. 1-17, 1985-1989.
17. Joel R. Fried, Polymer Science and Technology, Prentice Hall Professional, USA, 2003.
18. L.A. Utracki: Polymer Alloys and Blends, Hanser Publishers, New York, 1989.
19. A. L. Andrady, «*Plastics and the Environment*», J. Wiley & Sons, Hoboken, New Jersey, 2003.
20. A. Azapagic, A. Emsley, I. Hamerton ”*Polymers, the Environmental and Sustainable Development*” J. Wiley & Sons, N.Y. 2003.

Course: Unit operations (37874)		
Language: English		
Lecturer(s): Full Prof. Aleksandra Sander, PhD Assis. Prof. Krunoslav Žižek, PhD		
TEACHING	*WEEKLY*	*SEMESTER*
Lectures	2	30
Laboratory	2	30
Seminar	1	15
		Overall: 75
		ECTS: 6

PURPOSE:

Get acquainted with methods for characterization of coarse disperse systems.

To learn about transformations that occur during mechanical activity.

To study the effect of each granulometric property on the net response of separation and mixing technology.

To adopt the fundamentals that will ensure proper estimation and selection of optimal thermal separation process.

To adopt the core knowledge for equipment design with reference to energy savings and environmental impact.

THE CONTENTS OF THE COURSE:

Week 1
Introduction to unit operations. Mechanical and thermal separation processes.

Week 2
Basics of processes with particulate systems from macroscopic scale. Characterization of dispersed systems. Calculation examples.

Week 3
Basics of mechanical separation. Gravitational sedimentation. Equipment selection. Calculation examples.

Week 4
Centrifugal sedimentation. Theoretical background and equipment selection, calculation examples.

Week 5
Filtration and centrifugal filtration. Theoretical background and equipment selection, calculation examples.

Partial exam I: Characterization of dispersed systems, sedimentation.

Week 6
Fluid and suspension mixing. Impeller types. Design of mixing systems.
Basics of powder mixing. Theoretical background, equipment, equipment selection, calculation examples.

Lab assignment I: Filtration test.

Week 7
Comminution. Theoretical background, equipment, equipment selection, calculation

examples.

Week 8
Lab assignment II: Comminution kinetics.

Partial exam II: Filtration, mixing and comminution.

Week 9
Basics of thermal separation processes.

Week 10
Heat exchangers. Evaporation. Methods of energy savings in evaporation. Equipment classification and selection. Calculation examples.

Week 11
Crystallization. Kinetics, nucleation and growth mechanisms. Equipment classification. Calculation examples.

Lab assignment III: Floating head heat exchanger.

Week 12
Drying. Kinetics and mathematical description of the process. Energy savings. Equipment classification. Calculation examples.

Week 13
Partial exam III: Heat exchangers, evaporation, crystallization, drying.

Distillation. Implementation methods. Column design (height, diameter, number of theoretical units). Calculation examples.

Week 14
Absorption. Column absorption. Equipment classification. Calculation examples.

Lab assignment IV: Rectification.

Week 15
Extraction. Methods of process implementation. Equipment classification. Calculation examples.

Partial exam IV: Distillation, absorption, extraction.

Lectures are consecutively followed by lab tutorials and seminars.

GENERAL AND SPECIFIC COMPETENCE:

Acquiring knowledge necessary for equipment selection, definition of optimal process conditions and analysis of complex processes in chemical engineering.

KNOWLEDGE TESTING AND EVALUATION:

These are realised by implementing:
1. the screen of their knowledge via preliminary exams related to laboratory assignments, furthermore by four partial exams and finally by oral exam,
2. continuous monitoring of students: class attendance (both lectures and seminars), impression of seminar essay.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

By student questionnaire.

LITERATURE:

M. Hraste, Mehaničko procesno inženjerstvo, Hinus, Zagreb 2003.

M. Rhodes, Introduction to Particle Technology, John Wiley, London 1998.

A. Rushton, A.S. Ward, R.G. Hodlich: Solid –Liquid Filtration and Separation Technology, VCH Weinheim 1996.

K. Satler, H.J. Feindt, Thermal Separation Processes – Principles and Design, VCH Verlagsgesellschaft GmbH, Weinheim; 1995.

J.D. Seader, E.J. Henley, Separation Process Principles, John Wiley & Sons, Inc., 2006.

Internal scripts by:

Full Prof. Aleksandra Sander, PhD “Jedinične operacije u ekoinženjerstvu-Toplinski separacijski procesi” (available via Faculty pages at www.fkit.unizg.hr).

Assoc. Prof. Gordana Matijašić, PhD “Priručnik za vježbe iz Mehaničkih separacijskih procesa” (available via Faculty pages at www.fkit.unizg.hr).

Lectures for the course Unit operations by Full Prof. Aleksandra Sander, PhD and Assis. Prof. Krunoslav Žižek, PhD (also available via Faculty pages at www.fkit.unizg.hr).

Course: STRUCTURE AND PROPERTIES OF POLYMER MATERIALS

Material Science and Engineering

pregraduation; 3rd year (5th semester)

Language: English

Lecturer: Prof. Emi Govorčin Bajsić, PhD

TEACHING	WEEKLY	SEMESTER
Lectures	**2**	**30**
Laboratory	**1**	**15**
Seminar	**1**	**15**
		Overall: 60
		ECTS: 6

PURPOSE:

The course gives basic knowledge for understanding the structure and morphology of polymers, viscoelastic phenomena and their relationship with properties of polymers and polymer materials as well as understanding the procedure of microstructure processing and effects on the polymer properties.

THE CONTENTS OF THE COURSE:

1st week: Material. Classification of materials. Polymers, polymer materials. Specifics of polymer structure. Classification of polymer materials. Review of technological phases of production of polymer materials and formation of molecular and super molecular structure of polymers in individual phase process. Morphology of polymers. The influence of morphology on polymer properties.

2nd week: Microstructure of polymers. Real polymer systems. Morphology of polymers. Molecular structure, number and type of monomeric unit, form of chain, configuration, conformation and macromolecular size, average molecular weight. Intermolecular interaction in polymer.

3rd week: Super structure of polymers. Crystallinity and amorphous. Semicrystallinity. Degree of order. Two-phase structure of real polymer system, model of fringed micelle.

4th week: Static and dynamic structure of polymers. Dynamic structure and properties. Deformation. The change of conformation by heat. Phase transitions, glass transition temperature, melting temperature, flow temperature. Thermomechanical curve, thermomechanical curve for thermoplastic, duromer and elastomer. Degree of structure ordered.

5th week: Deformation orientation of condense polymers, anelasticity. Elastic and viscous components. Plasticity, viscosity and elasticity. Viskoelasticity. Conformation changes. Static mechanical properties. Stress/strain curve. Strength, elongation at break, elastic modulus, toughness.

6th week: Change of conformation of thermoplast, duromer and elastomer by stress. Stress/strain curve for each group of polymers. Temperature dependence of mechanical properties. Change of transformation with force and temperature.

7th week: Time dependence of deformation at constant stress. Time dependence of deformation at constant deformation. Change of conformation, diagram deformation/time. Elastic, viscoelastic and plastic deformation. Overall deformation. Creep and recovery. Creep modulus, relaxation. Time of relaxation.

8th week: Rheology of polymer fluid. Simple shearing. Newton -fluid flow. Non-Newton -fluid flow. Shear stress/shearing rate rheograms and dynamic viscosity/ shearing rate rheograms. Type of flow. Ostwald de Waal model. Melt flow index. Rheology models for viscoelastic polymer systems. Maxwell and Kelvin model. Thixotropy.

9th week: Rheology of rigid polymers. Polymer deformation. No elasticity. Dynamic mechanical properties, cyclic stress. Elastic and viscous component. Viscoelastic material. Loss angle. Relaxation time of kinetic unit in function of frequency and temperature. Dynamic mechanical spectra. Primary viscoelastic functions, loss modulus, storage modulus and tanδ . Linear, branched and crosslinked polymer systems. Amorphous and semicrystalline polymers.

10th week: Specific of thermoplastic, duromer and elastomer polymers. The effect of molecular and supermolecular structure on the DMA curve shape and values of storage modulus and loss modulus. Secondary viscoelastic function. Creep, recovery and creep modulus in function of temperature and time. Temperature shift. Master curve. Life evaluation of polymers. Dollitle model, WLF model and Arrhenius equation.

11th week: Thermal properties. Optical, electrical and magnetic properties. Stability of polymer materials. Aging, degradation, physical degradation. Chemical and physical aging process. UV, thermal, oxidative, mechanical, chemical and biodegradation. Structure changes and influence on properties. Ecological aspect of degradation. Stabilizers and antidegradants.

12th week: Physical aging. Conformation changes and influence on properties. The effect of temperature on physical aging. Flammability of polymers. Pyrolitic degradation. Self ignition. Combustion resistance. Flammable, after flame and non-flammable polymers. Flame retardance. Synergy of flame retardance.

13th week: Multiphase polymer systems. Polymer blends. Block polymers. Graft copolymers. Interpenetrating polymer networks (IPN). Crosslinked polymers. Temperature transitions. Mechanical properties. Composition, content and morphological structure single phase in multiphase polymer systems and effect on structure and properties. Modification and stability of multiphase polymer systems. Morphology structure. Continuous and non-continuous phase, phase inversion and effect on properties.

14th week: Additives. Fillers. Reinforced plastic (RP). Plasticizers. Foam able agents. Cellular plastic. The effect of additives on structure and properties of polymers. Additives of reactive types. Advantage and disadvantages. Polymer modifiers.

15th week: Possibility of programming specified structure and properties by additives. Structure and chemical constitution; condensation polymer. Design of multiphase polymer systems.

GENERAL AND SPECIFIC COMPETENCE:

Understanding of connection between structure and properties for polymer materials and modification of structure and properties.
Importance for production, processing and application.

KNOWLEDGE TESTING AND EVALUATION:

Partial tests (3 times) (written) or exam (written and/or oral)

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student questionnaire.

LITERATURE:

1. A.E. Woodwared, Understanding Polymer Morphology, Hanser, Munich, 1995.
2. D. W. Clegg, A. A. Collyer, Structure and Properties of Polymeric Materials, The Institute of Materials, London, 1990.
3. C. Hall, Polymer Materials, J. Wiley & Sons, New York, 1990.

Additional literature:

1. D.W. Van Krevelen, Properties of Polymers , Third Rev. Ed. Elsevier, Amsterdam, 1990.
2. V. Eisele, Introduction to Polymer Physics, Spring Verlag, N. Y., 1990.
3. H. L. Williams, Polymer Engineering, Elsevier Sci. Publ. Comp., N. Y., 1985.

Course: PROCESSING OF POLYMERS

Material Science and Engineering

graduation; 1st year (1st semester)

Language: English

Lecturer: Prof. Emi Govorčin Bajsić, PhD

TEACHING	WEEKLY	SEMESTER
Lectures	2	30
Field work (day)	2	16
Seminar	0	0
		Overall: 46
		ECTS: 6

PURPOSE:

Acquisition of knowledge about basic process of processing of thermoplastic, duromer, elastomers and composites with polymer matrix. The role processing process and additives in the determining microstructure and properties of polymers. Understanding differences between processing shaped product and initial polymer. Understanding structure and properties with the respect of materials and process features.

THE CONTENTS OF THE COURSE:

1st week: Review of technology process of processing of polymer materials. Classification of process of processing. Thermoplastic, duromer, elastomers and thermoplastic elastomer.

2nd week: Technology procedures for polymer improving and devices. Process of preparation polymer/additive and polymer/polymer compounds for individual group of polymers and additives.

3rd week: Melt mixing, pelletizing. Dispersion preparation. Liquid duromer resin. Blenders. Two-roll mill. Extruders.

4th week: Processing properties of polymers and polymer materials. Correlation of process features with processing and application properties of polymer materials.

5th week: Forming with chemical conversion and physical process from melt and dispersion.

6th week: Extrusion; profile production. Extruder; machine features. Operate adjustable features and features of polymer material. Extruder capacity. Swelling ratio.

7th week: Extrusion process and chill film, sheet and tubular film train. Calendering.

Orientation on calenders.

8th week: Moulding. Characteristic of three-dimensional process of processing. Moulds. Commonly, transfer and injection moulding. Construction features injection moulding machine. Cycles of injection moulding, p-v-T diagrams.

9th week: Thermoplastic semi-finished good forming from viscoelastic stage. Forming. Diagram of deformation state. Thermoforming, extrusion blow and injection blow.

10th week: Casting. Ordinary and rotational cast. Vinyl dispersions and physical process of curing. Coating. Dipping.

11th week: Foaming of reinforced plastic; duromer resins/glass fibre. Reinforced plastic thermoplastic, thermoplastic/ glass fibre, granulate, mould. BMC and SMC procedures.

12th week: Cellular materials. Reaction injection moulding (RIM).Soft, rigid and semi rigid foams. Blowing in block and mould.

13th week: Thermal process in processing. Features of material.

14th week: Thermal and energy balance of polymer processing.

15th week: Polymer waste in the phases in process of preparation and processing of polymer materials. Recycling.

GENERAL AND SPECIFIC COMPETENCE:

Acquisition of knowledge about basic process of thermoplast, duromer, elastomers and composite forming with polymer matrix. Understanding the structure design and properties of polymer materials through process of processing.

KNOWLEDGE TESTING AND EVALUATION:

Partial tests (2 times) (written) or exam (written and/or oral)

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student questionnaire.

LITERATURE:

Materials received on the lecture and web site materials.

1.R. G. Griskey, Polymer Process Engineering, Chapman & Hall, New York, 1995.

2.T. A. Osswald and G. Menges, Materials Science of Polymers for Engineers, Carl Hauser Verlag, Munchen,1995.

Additional literature:

1.J. Frados, Plastic Engineering Handbook, VNR, New York, 1976.

2.A. A. Collyer and L. A. Utracki, Polymer Rheology and Processing, Chapman & Hall, Hampshire, 1990.

Course: POLIMER BLENDS

Material Science and Engineering

pregraduation; 3rd year (5th semester); graduation; 1st and 2nd year (1st and 3rd semester)

Language: English

Lecturer: Prof. Emi Govorčin Bajsić, PhD

TEACHING	WEEKLY	SEMESTER
Lectures	**2**	**30**
Laboratory	**1**	**15**
Seminar	**0**	**0**
		Overall: 45
		ECTS: 4

PURPOSE:

Introduction to the polymer blends like multiphase systems, preparation and properties of blends. Knowledge of this topic is important for the development of the new polymer systems.

THE CONTENTS OF THE COURSE:

1st week: Historical outline of the development of polymer blends. Introduction to the polymer blends. Types and classification of polymer blends.

2nd week: Application of polymer blends. Structure and properties of polymer blends. Miscibility of polymer blends, parameters important for miscibility.

3rd week: The reasons for blending and how to select blend components. The methods of blend preparation: mechanical mixing, dissolution in solvent, polymerization, reactive blending.

4th week: Mechanical mixing of polymer blends. Preparation of polymer blends in extruder. Mixing of polymer blends in Brabender mixer. The influence of temperature, composition and ratio of components on the miscibility.

5th week: 1st partial test

6th week: Moulding of polymer blends. Moulding in mould. Injection moulding.

7th week: Miscible and immiscible polymer blends. Determination of polymer/polymer miscibility by DSC and DMA technique.

8th week: Crystalline and morphological structure of polymer blends. Kinetic of crystallization, isothermal and nonisothermal.

9th week: Reactive and nonreactive compatibilization. Compatibilization of polymer blends with mineral fillers.

10th week: 2nd partial test

11th week: Time-temperature superposition. Oxidative and thermal stability of polymer blends.

12th week: Degradation and ageing of polymer blends. Kinetic of degradation.

13th week: Polyolefin blends. Commercial important polymer blends.

14th week: Determination of structure of polymer blends. Application of different techniques for characterization of polymer blends. Mechanical properties of polymer blends.

15th week: 3rd partial test.

GENERAL AND SPECIFIC COMPETENCE:

Understanding and acquiring the knowledge about the polymer blends as multiphase systems. Preparation and characterization of polymer blends.

KNOWLEDGE TESTING AND EVALUATION:

Partial tests (3 times) (written) or exam (written and/or oral)

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student questionnaire.

LITERATURE:

Materials received on the lecture and web site materials.

1. L.A.Utracki, Polymer Alloys and Blends:Thermodinamics and Rheology, Hanser, 1989.
2. D.R.Paul, S.Newman, Polymer Blends, Academic Press, N.York, 1978.