Universität des Saarlandes (UdS) - Saarbrücken, Germany

Courses	ECTS
3DMN2 - 3D Analysis of Micro and Nanostructures - Advanced Methods (Mücklich) Introduction to modern tomography methods in materials science (X-Ray diffraction, Synchrotron, Atomsonde, FIB-&TEM-tomography), Basics of quantitative 2D and 3D microstructure analysis, 3D image processing and rendering, Morphological operations, FIB tomography processing: samples preparation, data recording, reconstruction and visualization, Introduction to a 3D image analysis software and laboratory in CIP-Pool, Simulation of materials properties in CIP-Pool, Project	**3**
AmoMet - Amorphous Metals (Busch) Close and far order in melted and solids bodies, Kinetic of order arrangement and heat transfer, Manufacturing process with liquid - solid transition via solid state reactions and via vapor deposition, Research methods for studying the glass transition Glass transition Kinetic, Crystallization processes, nucleation and mass transport, Viscosity of metallic melts and short-range order, Properties of Metallic glasses, Applications and processing methods for amorphous metals	**3**
BEUG2 - Diffraction Methods in Materials Science - Advanced Methods (Mücklich) Recapitulation of physical and crystallographic basics of the diffraction theory, Influence of microstrutural defaults (e.g. dislocations) on diffraction peaks, Profilanalysis and Rietveld method, Introduction to dynamic diffraction theory, application of Rocking curves and Reciprocal Space Mapping, Electronbackscattered diffraction (EBSD) and X-Ray Diffraction for quantitative texture analysis, Texture and Residual Stress Analysis assuming anisotropic materials properties, Thin Film Analysis Techniques: Diffraction assuming Grazing Incidence XRD (GIXRD), X-Ray Reflectometry (XRR)	**5**
ECPol - Experimental Characterization of Polymer Materials (Possart) Thermographic analysis, Calorimetry, Dynamic and mechanical analysis, Mechanical and technological tests, Ultrasound methods, Dielectrical spectroscopy, Infrarot and Raman spectroscopy, Neutron- and X-Ray Diffraction	**3**
EsMod - Empirical and Statistical Modelling (Bähre) The goal of this module is to achieve knowledge about principles and applications for statistical models. Beside learning basic terms and procedure methods students will be trained in data consumption and creating models by the use of examples	**4**
ExMech - Experimental Mechanics (Diebels) mechanic experiments for assessment of material parameters, Experiments, measurements of force- and distance values Control of the experiments and processing the data based on LabView, Methods for optimization and the inverse calculation for quantitative determination of material parameters	**4**
FBTec - Precision Machining Technologies (Bähre) Contents: Properties and requirements of technical surfaces; Edge influence created by manufacturing processes; Procedure methods overview and inset fields; Tense with uncertain geometrical edge: abrasion, process quantities, grind mediums and tools, conditioning, grinding, honing, lapping, finishing; micro abrasion operation; deburring- and curvature methods; methods for surface influence: spinning operation, plane casting, blasting, autofrettage	**3**
FEMM - Finite Elements in Continuum Mechanics (Diebels) Systems of Non-Linear Equations, Model Equations Linearization, Material Non-Linear Finite Element Analysis, Geometrical Non-Linear Finite Element Analysis, Numerical Handling of Elasticity and Plasticity	**4**
FeWe - Refractory Ceramics (Clasen) Contents: Degradation mechanism of FF-Materials while varying temperatures; Thermal mechanical properties of fire resistant materials in combination with new furnace design, redesigned processes, industrial processing and procedure methods; Characterization methods of thermal mechanical properties with higher temperatures (high temperature - tensile strength / pressure strength, creep behavior, creep behaviour, physical and chemical spalling behaviour, change in material quantities (Young's modulus, WAK, chemical resistance, thermal conduction))	**3**
FuWV - Functional Materials II (Mücklich) Assembling, properties and degradation mechanisms of contact materials Theoretical Fundamentals of Tribology and material properties optimizing possibilities, Manufacturing techniques and physical properties of semiconductive and superconductive materials, Applications of semiconductor and thermoelectric materials for energy conversion, Physical properties of nanoscale functional materials i.e. Carbon nanotubes	**4**
GlAnw - Glass-Processing (Clasen) Literature, glass as an economic factor, resources, storage and processing; Network former, network modifier, melt reactions, fining; Technical melt aggregates: pot furnace, hollow glass tank, day tank, "Low-Nox-Melter"; Fireproof materials, burner, heat transfer, heat balance, electronic melt; Fabrication of hollow glass: manual mode, feeder, blow-and-blow process, press-and-blow process, lightweight bottle, refining of hallow glass, comparison to plastics; Fabrication of pipes, pressed glass, fabrication and applications of glass fibres; Fabrication of flat glass: crown glass, lubber method, pulltrusion, float process, display glass; Manufacturing errors in glass fabrication: cords, stones, bubbles, devitrification, imperfect shape, cracking; Refinement of flat glass, heat protection glass, solar glass, sound protection glass, U and g values of vitrification, laminated and safety glasses in cars; Fire protection glass, mechanical and chemical functional layers, self-switching and switch able glasses, enamelling of glasses and metals; Fabrication of fused quartz: natural and synthetic resources, smelting, vycor glass, sintering techniques; Special glasses: filters, diaphragms, optical glasses, insulation glasses, treatment of glasses: separation, grinding, polishing, connecting, lens fabrication	**3**
GuKBe - Coatings (Clasen)	**3**

Overview coatings and coating technologies, economic aspects, functional properties: optic, abrasion, surface protection, tribology, electrical and thermal conductivity; Overview powder coating technologies, synthesis, milling, calcinations, characterization and classification of powders, conveyance and deposition; Thermal spraying methods: powder conveying, energy transport, kinetics, examples: plasma spraying (APS, high speed method), flame spraying; Electronic spraying: fundamentals and mechanism, ways of achievement, possible applications, electrostatic spraying; Glazes: requirements and compositions. Under-glaze, in-glaze decoration, noble metal décor, chandelier, resistance: acids (e.g. fruits), bases (e.g. dishwasher), engobes; Pile-on methods: manual painting, stamp print, decal, screen print, steel print, spraying, ink-jet, laser print (electrophotograhpy); Enamels: requirements, resources, treatment, pre-treatment, coating techniques, application examples, glass enamels (glass layers on glass); Low pressure vaporisation (PVD), CVD, PCVD, sputtering: DC, magnetron, reactive. Ion implantation, application of optical absorption, reflection and interference, heat insultation (TBC), TCO; Dip coating, spraying, roller application, sol-gel-films, thin films, multilayer films, optical applications; Electrochemical methods: electroplating, corrosion protection, décor, film with ceramic fillers, anodic oxidation, electroless coating; Post-treatment of films: burning-in, sintering, hardening, kiln , radiant heater, microwave, laser Film characterization, optical microscopy, SEM, TEM, optical spectroscopy: UV-VIS, IR, Raman, ellipsometry	
HLKer - Advanced Ceramics (Clasen) Introduction: Overview compositions, economic significance, process technology; Fabrication and properties of aluminium oxide, zirconium oxide, titanium oxide and other oxide ceramics; Carbon, modification, fabrication and properties, carbides Fabrication and properties of silicon nitride, aluminium nitride, boron nitride, precursor ceramics, molds and fibres; Fabrication and properties of electrical ceramics: capacitors, piezo ceramics, LTCC, NTC, PTC; Fabrication and properties of ion conductors, gas separation, sensors, HT-superconductors; Fabrication and properties of magnetic materials: ferrites, ferro fluids; Fabrication and properties of ceramic diaphragms, procedural applications; Fabrication and properties of optical ceramics: lamb bulbs, lenses, lasers, hard-facing; Fabrication and properties of biological ceramics: materials for dental and implant applications; Fabrication and properties of substrate materials for microelectronic devices	**3**
HMV1 - Methodology 3: High Resolution Microscopy I - SEM, EDS - (Vehoff) Contents: Physical and technical Fundamentals of scanning electron microscopy and micro-probe technique, Learning about measurement methods, field of use and limits of scanning electron microscopy and micro-probe technique; Learn to understand and judge the resulting pictures and data of the various imaging and measurement methods; Learn how to prepare samples and in practical experience knowledge about the function of a scanning electron microscopy and micro-probe technique	**4**
HMV2 - Methodology 4: High Resolution Microscopy II - TEM, SPM - (Vehoff) Students learn in detail the physical and technical fundamentals of various microscopy methods, where their resolution goes up to the atomic scale. Students learn about the field of use, possibilities and limits of the various measure methods. Students learn to understand the results of various techniques	**3**
IPhas - Intermetallic Phases (Busch) Classification of intermetallic phases from a crystallography and chemistry point of view, Classic ways to classify structures, Introduction of structure order and superstructures, Electronic parameters in Hume-Rothery, Grimm-Sommerfeld and Zintl-phases, Balance between packed density, preferential coordination, long range order and kinetics in topological high compact phases, half crystallized and amorphous metals, Crystal defects and mechanic properties of high symmetric bonding, Properties and applications of Ni- and Ti-aluminide, Shape memory alloys. High temperature materials with relevant electrical conductivity, Magnetic and superconductive materials	**3**
KauTech - Rubber Technology (Stommel)	**3**
KeKo - Ceramic Composites (Clasen) Introduction, history, terms, definitions, classification of ceramic composites, construction and production principles of CMC's Strengthening mechanisms: systems and technologies, fibre reinforced composites, Overview fibre materials, high temperature behaviour; Fibre interfaces and interphases, C-, BN-, oxide interphase formations, porous matrices, and porous coatings; Fiber-matrix production and design, 2-D and 3-D matrices, 2-D and 3-D winding structures, fibre coatings, composition and production, compatibility; Characterization methods, fibre reinforcement, matrix, interfaces, structure-property correlations, fracture mechanics, non-destructive testing, FEM modelling; Ceramic particle reinforced composites, manufacturing principles, ceramic nanocomposites, properties, applications, examples; Ceramic composites permeation, classification, systems, properties, applications; Ceramic composite layer, overview, classification, properties, applications Joining, building and bonding of ceramic composites, Interconnectors, ceramic composites machining; Biomorphic ceramic composites, manufacturing, properties, applications; Ceramic Foams, functionalization, properties, applications; Biomimetical and bio-inspired ceramic composites, lyotropic liquid crystalline templating, thin film templating, Bloc-copolymer templating	**3**
Kin - Kinetics (Busch) Students gain deeper knowledge and skills in the the following areas: the systems and changes of states in materials, especially in condensed states; the mechanisms of transformation and their detection by investigating the materials' microstructures; the rate-determining processes and their temperature dependencies; the role of non-equilibrium states in real materials.	**3**
Kleb - Adhesives and Adhesive Bonding Technology (Possart) Applications of adhesive bonding techniques, Adhesive raw materials, Techniques for processing of adhesive surfaces, Choice of adhesion materials, Adhesive applications and preparations, Construction technologies with adhesion bondings	**3**
KonM - Continuum Mechanics (Diebels)	**4**

Basic concepts of continuum mechanics, material body and material point Kinematic relations: functional movement, speed, deformation gradient, bias Tensors Balance equations for mass, momentum, spin, energy and entropy in physical and spatial representation Principles of Material Theory, Evaluation of the Dissipation inequalities for hyperelastic material behavior	
KorHT - Corrosion and High Temperature Oxidation (Busch) Types of interfacial reaction of a solid in contact with the environment; Thermodynamical Description of the Oxidation Process, Morphology of the Reaction Zones, Experimental Methods, Oxidation kinetics, measurement techniques and data analysis, Oxidation in Pure Metals and Particularities of Alloys; Corrosion in aqueous systems: electrochemistry, kinetics, and measurement techniques, Forms of corrosion and corrosion protection	**3**
Las1 - Laser Treatment of Materials - Interaction with Matter (Mücklich) Properties and generation of laser beam, Basic components from a laser; The different existing lasers, Biological effects of laser exposition and security aspects, Simulation of thermal conductivity and fields in materials	**3**
Las2 - Laser Treatment of Materials - Applications (Mücklich) Cutting and assembling, Generation and alloying, Laser-Cladding, Processeing using femtosecond and picosecond lasers Laser Interference Techniques for surface patterning and functionalisation of different material categories	**4**
MAIndF - Production Machines (Bähre) The goal of this module is to achieve knowledge about often used machines and systems for the finishing industrial goods. Beside a basic overview of the variation of machines and their field of use, students will learn about different models and their components. A big part will be focused on instrumental machines, systems for transportation, storage and manage, installation facilities	**4**
MaMo - Material Modelling (Diebels) One dimensional rheological models of linear viscoelastic and elasto-plastic material behaviour, Embedding the concept of internal variables in the framework of nonlinear continuum mechanics, Formulation of thermomechanically consistent, viscoelastic and elasto-plastic material models, Aspects of the numerical implementation of nonlinear models	**4**
MHiP - Materials under High-Pressures (Müser) Experimental understanding of material behaviour under high pressure Phase stabilities as a function of pressure Theory of Phase transformation	**4**
MMLKM - Methodik 8: Messmethoden lokaler Korrosionsmechanismen (Vehoff) Contents: Theoretical Fundamentals of local corrosion process and hydrogen embrittlement; Students learn measurement methods for Ex-Situ measure and In-Situ measure of local corrosion processes and hydrogen embrittlement, Students learn to understand the results of various techniques	**3**
MMPW - Material Models for Polymers (Stommel) Fundamentals of Continuum Mechanics, Fundamentals of Rheology, Material behaviour of polymers, Material Models for Polymers, Numerical implementation of material models	**3**
MSMSM - Microstructure Mechanics and Damage Mechanisms (Vehoff) Students learn about the influence of inhomogeneous microstructures on the macroscopic properties. They will learn to calculate simple, macroscopic material properties from complex data of inhomogeneous microstructures; they will get to know different damage-mechanisms and their cause; with the goal to improve the properties of materials, they learn how to investigate the basis of damage-mechanisms using physical experiments.	**3**
MTrib - Methods in Tribology (Müser) Hertz contact theory, General Models for single contact theories, Models for microscopical wear (Prandtl-Tomlinson Model), Non-Newtonian fluids; Hydrodynamical and elastohydrodynamical lubrication, Characterization of surface profiles, Contact mechanics of fractal surfaces (Persson Theory), Selected applications (e.g. contact temperature, wear mechanisms)	**3**
NanoT - Nanotechnology (Clasen) Overview fields of nanotechnologies: survey/analysis, ultra thin films, lateral structures, nanomaterials, ultra precision treatment, literature, physical fundamentals; Fabrication of nanoparticles: vacuum condensation, mechanical alloying, chemical precipitation, vapour deposition, laser ablation, electrodeposition; Sol-gel synthesis, organic silanes, combustion synthesis; calcinations, chemical analysis and phase determination, powder characterization; Measure techniques: microscopy, optical scatter methods, sedimentation, particle condensation, powder storage, powder extraction; Particulate materials, properties, fabrication, survey, fluidisation of powders, difficulties with nanopowders (respirable dust), electro spraying; Dispersion, states of aggregation, agglomerates, suspensions: introduction into colloid chemistry, electric and magnetic rheological liquids; Shaping out of low viscosity suspensions; electrokinetic effects, electrophoresis, hydrous and unhydrous systems, dielectrophoresis; Self-organization, sol-gel method for monoliths, colloidal gels, gelcasting, drying of gels with nanopores; Modification of green bodies, fabrication of secondary phases on nanoscale, quantum size effects, sintering of glass and ceramics out of nanopowders; 2D nanostructuring: nano lithography, mask technique; nano composites, effect pigments, light filter, functional nanolayers; Fabrication of 3D nanostructures, porous silicon, cluster matter, fullerenes, nanotubes, zeolite; Nanowires, meta materials, characterization of nanostructures	**3**
NEM1 - Nonferrous Metals I (Busch) From raw material to material and to final product; Technical aspects of the processing of raw material extraction and treatment; Metal extraction process from raw material; Production procedure from a metallurgical point of view Aluminum technology: manufacture, alloys, microstructure design; Titanium: applications, manufacture and properties Cooper materials: extraction, alloys and application fields; Others light and heavy metals, their uses and individual properties	**3**
NEM2 - Nonferrous Metals II (Busch)	**3**

Applications and requirements to high temperatures; Alloys families of Superalloys to use in propulsion systems and energy production; Superalloys: metallurgy, microstructure design, properties and manufacture process; Application fields and characteristics of metals with high melting point; Refractory metals: metallurgy, manufacture, microstructure influence and properties; Classification of composites with metal matrix; Heterogeneous properties, anisotropic microstructure; Manufacturing processes, properties and applications of composites; Requirements of materials for lightweight construction Light alloys with high specific strength; Metallic foams; Materials requirements for high electrical and / or thermal conductivity; Interaction between microstructure, conductivity and mechanical properties; Realization of the simultaneous demands with applications	
NMMMM - Methodology 7: Measuring on the Nano- and Micro-Scale (Vehoff) Students learn about the theoretic and technologic fundamentals for assessment of mechanical values to a micro- and nano scale	**3**
OptT - Optical Technologies (Clasen) Optical fibers: Introduction, telecommunication, optical basics: absorption, dispersion, refractivity profile, measurement; Optical fibers: Polymers as an alternative to glass materials, relevant optical effects (Faraday effect, optical isolator, fluorescence, laser); Non linear optical effects, stimulated Raman scattering, Brillouin Faser Laser, active fibers; Fabrication of optical fibers. High purity glasses: specifications, analytics, mechanical stiffness; alternative process; Photonic crystals and optical fibers. Integrated optics: elaboration, capacitors, optical sensors, gyroscope; Geometrical optics, refractive and diffractive elements, Imaging systems for retro-reflexion, self-focussed system; Laser for material processing, cutting, ablation; Radiation sources: lamps, LED, OLED; Materials with low thermal deformation: basis, glass-ceramics, controlled and preferential crystallization, zero expansion glass	**3**
OSHC - Organic Layers - Preparation and Characterization (Possart) Preparation of thin organic films - Physical and chemical processes, Methods for film thickness measurement, Microscopical imaging of thin films topography and morphology, Electron analyses: chemical composition, electronic structure and molecule vibrations, Photon spectroscopy, Chemical surface analysis with ion beams	**3**
OTech - Surface Engineering (Busch) Basic functions of surfaces: preparation, elaboration and tests; Deterioration of materials due to loading, wear and friction, tribological systems, corrosion and suitable possibilities for corrosion diminution with respect to loading systems; Mechanical surface treatment, solidification, residual stresses and influences of film thickness; Thermal treatments of steels: flame brazing, induction hardening, immersion hardening and laser hardening; Thermochemical treatments by nitriding, carbonitriding, boriding, metall diffusion and ion implantation; Chemical Vapor Deposition (CVD): types of reaction, processing, microstructure evolution; Applications of PVD and CVD in the communication technology; Welding process, microstructure evolution, properties and applications; Immersion coatings for corrosion protection; Electrochemical deposition processes, procedure and applications; Powder deposition processes and cladding processes	**3**
PFInt - Polymer-Solid Interphases (Possart) Students gain knowledge in the fundamentals of: Physical and chemical process in polymers and their phase boundaries; Physical and chemical mechanisms of adhesion; Structure development and properties of inter phases; Role of the inter phases in material compounds and composite material	**3**
PolVer - Polymer Composites (Stommel) Students gain knowledge in the field of polymeric composites, concerning: configuration, structure and classification; production engineering methods, specific for this class of materials; fields of application; guidelines of designing; calculation of dimensioning workpieces	**3**
PrMW / PrWT - Laboratory Materials Science (Vehoff) PrMW: Materials Science experimentation as: X-ray diffraction, spectroscopy of metals and polymers, corrosion, laser structuring, preparation and characterization of form bodies, simulation of material behaviour. PrWT: Materials Engineering experimentation as: Materials fabrication, Adhesive Bondings, Fatigue Strength, Corrosion, Measurements Residual Stresses, Elaboration, Characterization and further Processing of green body	**4**
ProdSys - Production Engineering (Bähre) The goal of this module is to achieve knowledge about the organisation and processing of companies. Beside a basic overview of their functions and connections students will be trained in planning, controlling and quality management	**3**
PuMet - Powder Metallurgy (Busch) Processes of powder elaboration, Powder characterization and determination of preparation properties, Powder preparation, Basics of sintering process for homogen and heterogen systems, Sintering process of systems with liquid phases Metal Injection Moulding, Test of sintering materials for the determination of thickness, porosity, mechanical and pattern properties, Economical consideration	**3**
QS - Quality Management (Stommel) Knowledge of quality trouble in the process; Analyze of relevant influence quantities; Creation of empiric models; Choice and application of static methods	**3**
SimKu - Simulation Methods in Plastics Technology (Stommel) Material behaviour and quantities; Material models and parameter guideline; Basic knowledge/executing in rheological structure mechanical simulations; analyze methods	**4**
Spanf - Machining Technologies (Bähre)	**4**

Overview and fields of application of separating production processes; Chipping with geometrically determined cutter, inter alia turning, drilling, galling, lowering, milling, planning, thrusting, broaching; Geometry and kinematics of chip generation Chip type and chip form; Forces, power and heat; Limiting criteria and abrasion; Tools and cutting materials Machinability; Solid cooling lubricants; Chipping with geometrically undetermined cutter; Electrochemical erosion; Spark erosion	
Stahl - Steel II (Busch) Recapitulation of the basic manufacturing and machining processes, classification and thermodynamical and kinetical characteristics of ferrous materials; Thermochemical observations of the slag - Bath Equilibria in the blast, while desulphurization, in the converter and in ladle metallurgy; Materials and economical observations of the iron forming; Microstructure, kinetic and mechanisms of phase transformations while htermomechanical treatment of Steel; Configuration, transformation behaviour, properties and applications of common steels; Joining technology of steels	**3**
ThS - Thermodynamics for Heterogeneous Materials (Possart) Comprehensive Fundamentals of: Thermodynamics of mixed phases; Theoretic knowledge of phase diagrams binary, tertiary and multi components systems; Chemical thermodynamics; Thermodynamic description of phase boundaries	**5**
TMP - Theoretical Materials Physics (Müser) (Classic) Condense materia electromagnetism (Debye Hückel Theory, Clausius Mossotti, Drude-Lorentz model, Kramers-Konig relationship); Mechanical Properties of Solids (Dynamic matrix, optical and acoustic phonones, limit of continuous, elastic constants from atomic interaction, Cauchy relation, symmetrical observations); Statistical mechanic of materials (Theory of linear answer, Fluctuation dissipation theorem, Ginzburg-Landau phase transition theory, Critical exponent); Electrons in Solids (Brillouin zone, Bloch's theorem, Hybridization, electrons semiclassic description, Boltzmann equation, electrons and holes conduction, point defects); Fermi surface and state density; Elementary excitations (phonones, magnones, excitones)	**8**
TPP - Technical Production Planning (Bähre) The goal of this module is to achieve knowledge about structures arrangement and event managing in producing companies. Beside a basic overview of the tasks, objects and methods for production planning, students will learn to understand the connections between various aspects	**3**
UVFT - Environmental Engineering Materials (Clasen) Students gain knowledge in selection, characterisation and application inorganic-non metal Materials for separation of substances, treatment of pollutant, detection of pollutant. Modern Material for energy transformation, energy storage and energy production	**3**
WerKV - Moulds in Plastics Processing (Stommel) Students gain knowledge in: Concept of tools; Construction of process and materials-suitable tools; Execution of calculations in tool manufacturing; Distinguish of problems in tools	**3**
WSET - Materials and Systems for Sustainable Energy Managing (Clasen) Knowledge about materials, components and systems for efficient energy usage; Basics in Energy technology, Limited resources and climate protection; Saving energy in housing (stationary) and mobile facilities; Energy support and energy storage; Current Production in a heating power plant; Heat pumps for heating/cooling; Renewable energy: overview and potentials; Case studies wind, water, geo thermals, photovoltaic, solar thermals	**3**
ZfP2 - Non-Destructive Testing of Materials II (Boller) Materials characterization (e.g. grain size, texture, residual stresses) employing non-destructive processes: micro- and macro-magnetismus, magnetic leakage flux test, photo-acoustic, thermography, ultrasound in anisotropic materials and ultrasound processes	**3**
Bio- and Nanomaterials (Arzt) Scaling laws and nanostructures, nanoparticle synthesis, nanocomposites and their applications such as optics and corrosion, bioinspired nanomaterials, and advanced techniques are in focus of this lecture. Additional laboratory courses will be offered.	**3**

Universitat Polytècnica de Catalunya (UPC) Escola Tècnica Superior d'Enginyers Industrials des Barcelona - Barcelona, Spain	
Courses	**ECTS**
Advanced Technical Ceramics and Inorganic Composite Materials (Anglada) The main objective of the course is to present the fundamental concepts for the design, fabrication and mechanical properties of advanced ceramics and inorganic matrix composites, mainly metal matrix composites. Contents: (1) General review on ceramic materials (4h), (2) Fundamentals of mechanical behaviour of ceramics. Elastic constants. Strength. Static and cyclic fatigue. (2 h), (3) Strength controlled by defects. Weibull probability function distribution. Effect on the strength of the specimen size and the type of test. (2 h), (4) Thermal shock resistance of ceramics. (2 h), (5) Toughening mechanisms in ceramics: particles, whiskers, phase transformation and fibres. (2), (6) Zirconia ceramics. Microstructure processing and properties. (2 h), (7) Si3N4 and Sialons, SiC, Al203 and other engineering ceramics (2 h), (8) Metal Matrix Composites (MMC). Types of MMCs. Reinforcements. Fibrous materials: carbon fibres, boron fibres, oxide fibres, nonoxide fibres. Particles: silicon carbide, tungsten carbide. Matrix Materials. (2 h), (9) Processing MMCs. Liquid state processing. Solid state processing. Gaseous state processing. (2h), (10) Interface. Crystallographic nature of the interface. Wettability. Types of bonding .Measurement of interfacial bond strength. (2h), (11) Elastic Constants of a fibre reinforced composite. Physical properties: density, coefficient of thermal expansion. Thermal conductivity; electrical conductivity. Thermal stresses in composites (4 h), (12) Strength of MMCs. Strengthening mechanisms. Monotonic behaviour of continuous fibre reinforced MMCs. Criteria for debonding and crack deflection at an interface. Fibre Pull out. Interfacial reactions. Monotonic behaviour of discontinuously reinforced MMCs. Fracture toughness (4 h)	**5**
Bioceramics (Ginebra) The goal of the course is to provide the scientific bases for the knowledge on ceramic materials used in medical applications. The different types of ceramic biomaterials are presented. Their structure, physical-chemical and mechanical properties, together with their interactions with the biological systems are analyzed. Contents: 1. Introduction. Ceramics as biomaterials. Historical perspective and current state, 2. The biological ceramics. The biominerals, 3. Structure and properties of hard tissues, 4. Type and Classification of bioceramics, 5. Biostable ceramics, 6. Calcium phosphate ceramics, 6.1. Physics and chemistry of calcium phosphates, 6.2. Calcium phosphate ceramics, 6.3. Calcium phosphate cements, 7. Glasses and glass ceramics, 7.1. Silicate-based glasses, 7.2. Phosphate-based Glasses, 8. Ceramic coatings, 9. Bioceramics applications	**5**
Composite Materials (Pagés) 1.Introduction to the conventional Composite materials and Nanocomposites: concept, main components, Technical classifications and Industrial Applications, 2. Reinforced components in composites and their influence on behaviour of Material: Fibres and non- fibrous Reinforcements. Functional particles. Nanoreinforcements, 3.Matrices components in Composites and their influence on behaviour of Material: organic, metallic and ceramic matrices. Adhesion matrix-reinforcement. Prepregs., 4.Structures of pieces of Composites and Nanocomposites, related properties, performances and fracture, 5.Composites Processing and Quality Control. Prerequisites: Polymeric and Composite Materials. Mechanical behaviour of Materials. Fatigue and Fracture of Materials.	**5**
Corrosion and Degradation of Materials (Iribarren & Fernandez) This course devotes 3 credits to electrochemical corrosion of metals and alloys and protection against corrosion by means cathodic protection, metallic and organic coatings. The second part (3 credits) is related with the high temperature corrosion (dry corrosion, oxidation) and wear in ceramic and metallic materials. Prerequisites: Basic Bachelor courses in Chemistry, Physics and Fundamentals of Materials Science.	**5**
Design, Ecodesign and Materials Recycling (Maspoch) The objective of this course is provide the students the knowledge and tools required to design a plastic part while considering the manufacturing aspects that influences design. In second term the course gives an introduction to ecodesign concept. The basic strategies of ecodesign are explained in detail. Finally the plastics recycling technologies are described. Contents: 1. DESIGN, 1.1 Introduction. Methodologies. Quality and design. Basics on plastic design, 1.2 Introduction to the Finite element analysis (FEA), 1.3 Structural and mechanical design. Examples. Manufacturing aspects, 1.4 Plastic design guidelines, 2. ECODESIGN, 2.1 Introduction, 2.2 Life cycle analysis, 2.3 Ecodesign methodology, 2.4 Ecodesign strategies, 2.5 Practical examples: Automotive, Construction, Packaging, Furniture, 3. RECYCLING, 3.1 Plastic wastes, 3.2 Plastic recycling alternatives, 3.3 Mechanical recycling, 3.4 Chemical recycling, 3.5 Thermal recycling, 3.6 Exemples of recycled parts, 3.7 Biopolymers.	**5**
Development of competences for the search and publication of information in Materials Science (Library staff) The value of information in the research process. Search strategy and information recovery. Information search tools Typology of document of the information sources on materials science and engineering. The evaluation of information. The management of information. The evaluation of the research activity. The principles and phases of publication.	**2**
Failure Analysis and Quality Control in Materials Technology (Mateo) Procedures and techniques for the analysis of failures of all types of materials are the objective of this course. An important part of the course is devoted to non-destructive testing, as a procedure to inspect and prevent failures in service. Prerequisites: Fundamentals of Materials Science.	**5**
Fracture and Fatigue (Anglada)	**5**

Failure of materials and structures. Stress concentrators. Introduction to linear elastic fracture mechanics. Strain energy release rate and specific fracture energy. R-curves. Stress intensity factor and fracture toughness. Plastic zone. Standards methods for measuring plain strain fracture toughness. Introduction to elastic-plastic fracture mechanics: CTOD and J-Integral. Micromechanisms of fracture. Microstructure and fracture toughness. Fatigue under constant amplitude cyclic loading. Cyclic deformation under strain control. Low and High Cycle Fatigue. Influence of surface conditions on fatigue life. Crack initiation. Crack propagation. Mechanisms influencing crack growth. Short cracks. Fatigue of non-ductile materials. Corrosion fatigue. Fatigue at high temperatures. Fatigue under variable amplitude cyclic loading. Prerequisites: Fundamentals of Materials Science and Technical Mechanics.	
Life tissues, substitutive materials and biointerfaces (Engel) 1. Introduction to biology. Tissues (bone, cartilage, muscles, vessels, etc), 2. Implants and devices for biomedical applications, 3. Surfaces. Properties, characterization techniques. Surface modifications, 4. Cell-materials interactions. The course implies theory and practices on surface characterization and cell-materials interactions. Prerequisites: Fundamentals on Materials Science	**5**
Light Alloys (Calvo) Description of the light metals and their alloys with special regard to their physical and mechanical properties as well as their technological applications. Physical metallurgy of aluminium alloys. Wrought aluminium alloys: (work-hardening of aluminium and its alloys and non-heat treatable alloys, heat treatable alloys). Cast aluminium alloys (alloys based on the Al-Si system, Al-Cu system, Al-Mg and Al-Zn-Mg). Magnesium alloys (melting and casting, influence of the Zr, wrought magnesium alloys), Titanium alloys (α, α+β and β alloys, fabrication and engineering performance). Prerequisites: Basic Bachelor courses in Physics and Mathematics and fundamentals of Materials Science	**5**
Materials Selection in Mechanical Design (Cabrera) The subject will provide criteria for materials selection in terms of their properties and the shape obtained during processing. Aditionally, the effect of the processing method on the mechanical properties and economical cost of the piece is also analized. Special attention is paid to the selection criteria for a given application as well to the interchange of a given material in a given piece. Lectures are preferibly oriented to the Asbhy selection method. Contents: Process of Design. Steps and examples. Materials Selection. Behaviour and characteristics of materials. The process of materials selection. Evaluation methods. Ratio cost – properties. Shape effect. Examples Manufacturing processes. Types and classification of manufacturing processes. Economical aspects Interaction between materials, processing technology and design. Design of cast, forged, sheet metal formed, machined, sintered and soldered pieces. Desing after the beahvioir. Selection maps. Examples.	**5**
Mechanical Behaviour of Materials (Alcala) Mechanical behaviour of materials: metals, polymers, ceramics and composites. Influence of temperature, strain rate, process and microstructure. Characterisation methods. Constitutive equations. Relationships between stress and strain. Elasticity. Elastic constants. Yielding. Yield criteria. Yield surface. Viscoleastic linear behaviour. Creep and stress elaxation. Boltzman superposition principle. Mechanical models. Dynamic mechanical measurements. Complex moduli. Plastic behaviour and strengthening mechanisms. Slip systems. Twinning. Dislocations. Plastic deformation of polycrystals. Solid solution strengthening. Second phase strengthening. Other strengthening methods. Prerequisites: Basic Bachelor courses in Physics and Mathematics and Fundamentals of Materials Science	**5**
Metals and Alloys (Calvo) Description and applications of the most significant metal based alloys from an industrial perspective. Ferrous alloys. Steels. Carbon steels. Alloyed steels. Stainless steels. Tool steels. Heat treatments. Cast irons: Grey and Ductile iron. Copper and copper alloys: Brasses, Bronzes, Cuproaluminium. Light alloys: Aluminium and aluminium alloys, Magnesium and magnesium alloys, Titanium and titanium alloys. Superalloys. Soft alloys: Lead, Tin and Zinc alloys. Precious metals. Prerequisites: Basic Bachelor courses in Physics and Mathematics and fundamentals of Materials Science	**5**
Metals Technology (Prado) The aim of this subject is to provide the student with the necessary knowledge of the different metal forming processes; this will be the basis for further studies on the subject. The subject is an introduction to the metal forming technological processes. The course focuses in four basic processes: forming by plastic deformation, model, welding and pulvimetallurgy. Special emphasis is put on the influence of the material, its micro structural transformation and its final mechanical properties. The main industrial processes and their future development perspectives are also described. Contents: 1. Forming by plastic deformation: Grounds (7h) Mechanical analysis of plastic deformation. Influence of the temperature. Influence of the rate of deformation. Influence of friction. Static and dynamic recrystallisation. Weaving. Bundle. Resolution of exercises, 2. Forming by plastic deformation: Processes (7h) Lamination. Forgery. Extrusion. Sheet forming. Formability criterion. Forming defects. Resolution of exercises. Molding: Basics (7h) Theory of solidification: Nucleation and growth. Alloying effect. Solidification in a mold: structure, porosity, segregations. Resolution of exercises. Molding: Processes Expendable molds: Filling systems, feed systems. Kinds of expandable molds. Permanent molds: gravity and injection. Resolution of exercises. 5. Welding: Basics (6h) Thermal analysis of the welded union. The molten area. Transformations in the heat affected zone. Weldability criteria, 6. Weldering: Processes (6h) Oxyfuel Welding. Shielded Metal Arc Welding. TIG, MIG and MAG welds. Projection weld. Friction weld. PLASMA weld. LASER weld. Oxyfuel Gas Cutting. Resolution of exercises, 7. Pulvimetallurgy (5h) Description of the process. Type of Pulvimetallurgy. Compaction. Sintering. Industrial application of Pulvermetallurgy. Surveys.	**5**
Micro-Mechanical Design of Materials, Nanomechanics and Coatings (Llanes)	**5**

The main objective of the course is to let students know the most relevant aspects on the microstructural design of materials based on the deformation and damage micromechanisms as well as the mechanical response at microand nanostructural scales, both at bulk and surface (coatings) levels. The specific objectives of the course are: • To recognize, through a thorough presentation of deformation and damage micromechanisms, the relevance of microstructure on the final performance of advanced materials. • To present and understand the mechanical aspects of nanotechnology, including concepts and methods used in micro- and nanomechanical simulations. • To provide students with series of concepts that allow them to understand and analyze surface modification processes based on coating deposition and its corresponding mechanical and tribological characterization. Contents: 1. Micromechanics of deformation, damage and fracture mechanisms in metals, ceramics and metal/ceramic composites (2h), 2. Microestructural design of materials under structural considerations (2h), 3. Mechanical behavior of nanocomponents: nanotubes, structural nanoelements, soft nanomaterials (polymers, gels), high strength nanoestructural materials (laminar composites, nanocrystals) (4h), 4. Mechanical characterizacion at the nanometric level (nanoindentation, AFM, and other novel methods). (4h), 5. Computer modelling techniques at micro- and nanometric scales (6h), 6. Surface modfication technology. Industrial coatings. (2h), 7. Mechanical integrity and contact response of coatings. Microstructural and tribomechanical characterization of coatings. (6h), 8. Microstructural design of coatings from a functional-driven perspective (4h), 9. Practical activities: lab, practical exercises and small projects (15h)	
Microstructural Materials Characterisation (Manero)	**5**
1. - Optical microscopy. Fundamentals and techniques. Examples of microstructures. Metallography of ferrous and non ferrous alloys 2.-Properties of X-rays. Geometry of Crystals. Diffractometer measurements: determination of Crystal Structure. Indexing patterns of cubic and non cubic crystals. 3.- Electron-sample interactions. Electron microscopy of materials. Fundamentals and techniques (SEM, TEM, ESEM). Samples preparation. Electron diffraction. Indexing single crystal pattern. 4.- Others techniques (AFM, Contact angle measurements, Toff-SIMS) Prerequisites: Basic Bachelor courses in Physics and Mathematics and Fundamentals of Materials Science	
Modelling of plastic deformation of metals (Riera)	**5**
To introduce the student to the basic concepts of the classical theory of plasticity. To define the basic constituent models which represent the behaviour of conventional, porous and granular metallic materials under plastic deformation. To introduce the student to the implementation of these models in commercial calculation programmes by means of the Finite Elements Method so as to design and control plastic forming processes. Contents: Mechanics of forming by plastic deformation. Deformation zone in a plastic forming process. Tridimensional state of tensions. Deformation state. Resolution of illustrative problems (8 hours). Basic concepts of the theory of plasticity. Creep criterion. Incorporation of the strain hardening. Strain-stress ratio in the plastic regime. Examples. Resolution of exercises (10 hours). Anisotropy effects in the plastic behaviour of metals. Applications. Examples. (4 hours). Mechanic behaviour of metallic materials at high temperatures. Dynamic recrystallization and restoration. Superplasticity. Applications. (6 hours). Plasticity models applicable to porous and granular metallic materials. Examples. Applications (2 hours) Analysis of problems in plastic forming. Equations which describe the mechanics of the forming. Resolution methods of the system. Examples. Applications. Resolution of exercises. (5 hours). Simulation of processes by means of the Finite Elements Method. Use of commercial numeric calculation programmes for the design and the control of processes. Simulation exercises. (10 hours).	
Nanotechnology (Cabrera)	**5**
The general aim of the subjet is to provide the bases necessary to understand nanomaterials from the point of view of their synthesis, their properties and their applications. Since materials on this scale display new and mproved characteristics in relation to traditional materials, the lecture will be focused in the description of these new properties and how obtaining nanoestructured materials. The generic competences that the student will reach will be a) capacity to understand and rationalize the process of selection of materials, b) capacity to develop manufacturing techniques and knowledge of characterization techniques, c) capacity to work in equipment and e) capacity of written and oral technique communication. Contents: Introduction: Definitions. First approach to nanoestructured materials. Synthesis. Formation of clusters and nanoparticles from supersaturated vapour. Synthesis by chemical routes. Synthesis of semiconductors. Formation of nanoestructures by mechanical milling. Multilayer materials Processing. Nanoestructured materials sol-gel. Consolidation of nanocristalyne materials by compaction and sintering Characterization. Nanoestructure of metals and ceramics. Scanning Techniques. Atomic diffusion in nanoestructured solids Properties. Chemical properties. Mechanical properties. Magnetic and optical properties. Electrical properties. Special Nanomaterials. Fullerens and nanotubes. Biological nanomaterials. Nanofabrication and nanoelectronics. Technological impact.	
Natural Materials and Biomaterials (Ginebra)	**5**

The course describes the natural materials, or biological materials, from the perspective of their composition, structure and properties. The interest of these materials, from the point of view of optimization and efficiency of the design, is pointed out, as well as the role they have as models for the design of artificial materials (biomimetic approach). Both vegetal and animal tissues are described. The present and potential applications of materials in the field of health sciences are presented. The role of biomaterials in the substitution or regeneration of the natural tissues with therapeutic or diagnostic purposes is described. The different types of biomaterials, their characteristics and the hostbiomaterial interactions are revised. The techniques that allow evaluating the biocompatibility of biomaterials are portrayed. Specific goals: - Knowing the composition, structure and properties of the most important natural materials. - Knowing the contributions of biomimetics in the design of novel materials. - Familiarizing oneself with the common characteristics and the differential features of the different types of materials used in medicine. - Knowing the basic principles of biocompatibility of materials for medical applications. - Discerning the fundamental criteria that have to be fulfilled for that a material can be implanted. - Knowing the biological principles that affect the interactions between the host organism and the biomaterial (host response) and relating them with the in vivo performance of the biomaterial (biomaterial response).	
New perspectives in Materials Science (Llanes) 1. Introduction 2. Revision to some aspects of the structure of matter: Basic elements. Two states of matter: order and disorder. The perfect gas. Crystals. Crystalline solids. Liquids. Non-crystalline solids. Between order and disorder. Composite materials, suspensions and colloidal solutions. 3. Challenges and perspectives: Photonic Materials. Materials for Information Storage. Smart Materials. Biological Materials and Biomimetics. Biomedical Materials. Materials for Clean Energy. Porous Materials. Diamond and Hard Materials. The New Polymers. Surfaces, Interfaces and Nanotechnology. Prerequisites: Fundamentals of Materials Science.	**5**
Physical Metallurgy (Prado) Structure of solids. Defects in solids. Equilibrium phase diagrams. Solidification and diffusion in the solid state. Phase transformations in the solid state. Kinetics diagrams of phase transformations. Thermal treatments. Prerequisites: Basic Bachelor courses in Physics and Mathematics and Fundamentals of Materials Science	**5**
Physical properties of Materials (Jiménez) Introduction to quantum phyisics. Density of states in solids. Fermi statistics. Electrical properties of materials. Conductivity in metals. Intrinsic and extrinsic semiconductors, effect of the temperature. Basics of semiconductor devices. Processing of semiconductors. Dielectrics: polarization, ferroelectricity, piezoelectricity and piroelectricity. Introduction to magnetism. Magnetic field in the materials. Paramagnetism, ferromagnetism, antiferromagnetism and ferrimagnetism. Magnetic domains. Soft and hard magnets. Superconductivity. Interaction between electromagnetic radiation and materials. Absorption, transmission, colour, luminescence, phosphoresce, electroluminescence, photoconductivity. Photoelectrical effect. Birefringence. Polarization. Thermal properties of materials, Thermal properties of metals, ceramics and polymers. Thermoelectical phenomena. Thermocouples. Prerequisites: Basic Bachelor courses in Physics and Mathematics and Fundamentals of Materials Science	**5**
Plastics Materials: Characterization and Applications (Santana) Advanced thermal characterization techniques. Mechanical and fracture behaviour of polymers. Synthesis, main properties and degradation mechanisms during processing/perfomance related to structure of main thermoplastics families. Green Polymers. Addtive technology: satabilizers, processing aids, impact modifiers, aesthetic modifiers and of specific use. Prerequisits: Polymer and composites.	**5**
Polymers and Composites (Martinez) Polymer synthesis and structure. Classification. Relationship between structure and thermal, rheological, chemical and mechanical properties. Viscoelasticity. Yielding process in polymers: deformation mechanisms. Introduction to main manufacturing process: extrusion, injection moulding and other processes. Introduction to Polymer composites: polymer-polymer and polymer-inorganic fillers and fibers. Prerequisites: Basic Bachelor courses in Physics and Mathematics and Fundamentals of Materials Science	**5**
Surface Technology (Herrero / Calvo) Description of the classical and modern surface treatments with regard to industrial applications. Treatments which involve plastic deformation at the surface such as shot-peening and cold rolling. Treatments which induce changes of the chemical composition at the surface such as carburization, nitriding and carbonitriding. Treatments which change the microstructure at the surface such as induction hardening and flame heating. Plating. Coating. Painting Hard coatings. CVD, PVD, ion implantation. Prerequisites: Fundamentals of Materials Science.	**5**
Technological Biopolymers (Muñoz)	**5**

General objectives: The biopolymers are studied from the point of view of their use as materials of industrial interest. The study is centered on the structure-properties conceptual axis and includes the synthesis and biosynthesis methods, and their utilization in traditional sectors as well as in advanced technological applications. Specific objectives: To know the biochemical mechanisms and biotechnological methods of generation and production of biopolymers. To know the chemical structure-basic properties relatonship in the biopolymer systems. To know the mechanisms and biodegradation processes taking place in biopolymers. To know the technically interesting properties and industrial applications of biopolymers. Contents: 1. Introduction to macromolecular chemistry. Monomer and polymer. Composition and constitution. Clasification of polymers. Copolymers. Configuration. Molecular sizes. Exercises. (6h), 2. Structure and properties of polymers. Molecular conformations. Coils and helices. Cristalline sructures: lamelles and spherulites. Supramoleculas structures. Chemical, thermal and mechanical properties. Other properties. Exercises. (6h), 3. Proteinic materials. Aminoacids. Peptides. Polypeptides. Peptide conformations. Proteinic fibers.: silks, wools and colagen. Queratin. Hydrogels: gelatines. Exercises. (6h), 4. Polysaccharides. Monosaccharides. Disaccharides. Starch and cellulose. Cellulosics cements. Pectin. Cellulosic fibres. Regenerated cellulose. Thermoplastic derivatives of cellulose. Chitin and chitosan. Mucopolysaccharides. Exercises. (6h), 5. Natural rubber. Isoprene. Obtention of natural rubber. Structure and properties of natural rubber. Vulcanisation. Synthetic natural rubber.(4h), 6. Biotechnological polymers. Industrial biotechnological process. Micro-organisms. Polyalkanoates. Poly(glutamic acid). Other biotechnological polymers. (4), 7. Biodegradability. Basic concepts. Evaluation methods. Synthetic biodegradable polymers. Polyesters and polyesteramides. Structure and properties. Starch based biodegradable blends (6h), 8. Functional and nanostructured biopolymers. Biosurfactants. Membranes and liposomes. Drug-delivery systems. Adhesives and floculants. Hierarchized structures. Cellulose-lignin and mineral-protein structures. (10h), Laboratory sessions of polymer characterization. FTIR and NMR spectroscopies, GPC chromatography, calorimetry, thermogravimetry and mechanical properties.

Materials Joining Technologies (Mateo)

5

The processes of materials joining are the fundamental topic. Specific objectives are:

- To know of the main technologies of metals welding
- To understand the metallurgical changes in the welded material and their influence in the mechanical properties
- To understand the basic aspects of the adhesion, evaluation of the adhesion and the essential aspects about the effectiveness of the adhesive joints

Prerequisites: Fundamentals of Materials Science

Technology of Plastic (Martinez)

5

Specific objectives:
a) Deep insight on Rheological behaviour of polymers and its relationship with molecular structure.
b) Deep insight on processing/manufacture techniques applied to plastic materials and review their lay-out (production line): Extrusion, Injection moulding and related techniques based on them. Thermoforming. Rotational moulding. Advanced processing techniques.
c) To give a review on selection and design criteria of forming tools (moulds or dies) and processing parameters in order to rise the quality of final piece.
Generic objectives:
a) Practical problems resolution in order to promote the development criticism analysis and scientific methodology in processing of plastics materials.
b) To promote the work in group in laboratory
c)To extent oral and written comunication habilitéis in coherent and concise way through writing, oral exposition and debate of laboratory work reports.
Contents:
Flow in polymeric materials: Rheological behaviour of polymers. Used techniques in its study. Factors that influence this behaviour. Elastic effects on plasticized (molten) polymer. Industrial cases discussion. Extrusion and aids techniques: Machine and theoretical operation curves. Blending and compounding. Main production lines: fibers, tube and pipes, wire production, extrusion-calender, co-extrusion, films and sheet production, blown-extrusion. Aids techniques: Thermoforming. Rotaional moulding.
Injection moulding: Machine description and processing parameters. Moulds tools and their design criteria. Defects on injection moulded parts. Rheological simulation of mould filling. Industrial cases discussion.
Advanced processing techniques: Multi-parts injection moulding. Overmoulding. Fluid assisted injection moulding: water (WAIM) and gas (GAIM). Mould injection with melting male. Lamination in mould. PUSH-PULL, IMD, RIM, MUCELL, smart-blendig.

Tutorised research work (All professors)

5

First part. The value of information in the research process. Search strategy and information recovery. Information search tools Typology of document of the information sources on materials science and engineering. The evaluation of information. The management of information. The evaluation of the research activity. The principles and phases of publication. Second part: Presentation of the state of the art of a specific subject on MSE under the supervision of a lecturer using information tools developed during the first part of the course.

Luleå tekniska universitet (LTU) - Luleå, Sweden	
Courses	**ECTS**
T0004T – Materials Science & Engineering (Wallström) The content of the course is basic materials science in-cluding metallic- and polymer materials. Metals (70%): Metallic properties: Crys-tallography, Crystal imperfections (basic disloca-tion theory). Diffusion and reaction kinetics. Mechanical proper-ties, plastic deformation and failure. Hardening mechanisms. Al-loys, phase diagrams and solid state transformations. Steel and thermal treatment: Microconstituents, alloying elements and thermal treatment. Material physics. Corrosion Polymers (30%): Poly-mer structure, molecular weight, crystallinity, glass transition, visco-elas-ticity, rubber, composites, additives, forming techniques, ma-terial knowl-edge, yielding and deformation mechanisms. Prerequisites: Basic competence for university studies	**7,5**
T0003T – MaterialsTechnology & Materials Selection (Wallström) Corrosion and degradation of metallic materials, with special regard to corrosion mechanisms, resistance to attack by various environments, and measures to prevent or reduce degradation. The properties of ceramic materials related to structure, the different fabrication steps, machining and mechanical testing. Properties and areas of application for conventional ceramics, glass, glass ceramics, refractory ceramics and high performance ceramics. Polymers and polymer composites and production methods Production and manufacturing methods for metallic materials Material selection Prerequisites: T0005T or equivalent	**7,5**
F0019T – Solid State Physics M (Lehto) Similair to MTF106 with quantum physics. Prerequisites: Physics & Mathematics according to the admission prerequisities	**7,5**
T7008T – Phase Transformations (Ion) Thermodynamics and kinetics of alloys: binary and ternary sys¬tems; kinetics of transformation. Diffusion: interstitial and substitutional diffusion, the relationship between macroscopic dif¬fusion and atomic mechanisms; mass transfer in porous materials and other transport phenomena. Interfaces and surfaces: structures and properties of surfaces, grain boundaries and interphase inter¬faces, the effect of inter¬faces on transformation. Solidification: Nucleation in pure metals, growth of a pure solid and alloy solidi¬fication. Diffusional transformation: general theory of nucleation and growth; important phase transformations such as precipitate, massive, spinodal, ordering transformation etc; trans¬for¬mation of steels. Diffusionless transformations: the crystallography and ki¬netics of nucleation and growth of Martensite transformation. Prerequisites: T0005T or equivalent	**7,5**
T7002T– Materials Modeling (Joffe) Multi-scale nature of materials (nano-, micro-, macro-) Link between different size scales Hierarchical approach in Material modelling Atomistic method in materials modelling, aspects of different approaches will be presented, such as: total energy calculations, molecular dynamics simulations ab intio methods General overview of numerical techniques in materials modelling Application of the numerical techniques to solve material modelling problems will be addressed during the course and some of the commercial software packages will be discussed. Homework and laboratory exercise assignments will be solved by using such software. Prerequisites: T0005T, F0019T: Solid states Physics for M, T0003T: Materials Technology & Materials Selection and MPM036 or equivalent	**7,5**
T7003T– Advanced Materials Characterisation Techniques (Ion) The students will be able to use some of the most important materials characterization methods and choose the most suitable characterization technique. They will be able to operate standard analysis tools for material characterization, including scanning electron microscopy, TEM, x-ray diffractometer, thermal analysis (DTM & DSC) and IR. Prerequisites:T0005T, F0019T: Solid states Physics for M, T0003T: Materials Technology & Materials Selection and T7008T or equivalent	**7,5**
T7001T – Deformation and fracture (Vuorinen) The course will cover mechanical behaviour such as plasticity, creep, fatigue and fracture toughness of metals, polymers and ceramics from both a macroscopic and microscopic point of view. Basic theories and modern development with material science and fracture mechanics will be emphasised. Prerequisites: T0005T or equivalent	**7,5**
T7005T – Aeropace Materials (Varna)	**7,5**

The material classes analyzed in this course are high performance materials like light weight alloys, superalloys, ceramics and different types of composites including materials modified on nanoscale. Methodology will be given to determine properties of these multiscale materials on all considered length scales. The properties most important for design in the aerospace applications are performance at high mechanical loads, extreme temperatures and material aging and fatigue due to extreme environmental effects. Processing methods will be considered in relation to desired material performance. Durability and damage tolerance will be accessed by analyzing degradation, creep and damage mechanisms. Methodology for structural analysis will be given and training performed. Prerequisites T0005T, T7012T, F0019T: Solid states Physics for M, T0003T: Materials Technology & Materials Selection and T7008T or equivalent	
T7006T – Nanostructured Materials & Nanotechnology (Soldatov) The course will cover nanostructured materials and phenomena occurring when the length scale of the constituents are in the nanometer range. Emphasis will be put on interface phenomena since nanostructured materials contain a large fraction interfaces. The course will give examples and potentials for the future of nanotechnology. Generally applicable techniques for the preparation of bulk nanostructured materials, thin films, patterned nanostructures such as sol-gel, thin film and self-assembling techniques will be discussed as well as high spatial resolution techniques for the characterisation of nanostructures. Prerequisites: MPM033, MTF132: Solid states Physics for M, MPC001: Materials Technology & Materials Selection and MPM036 or equivalent	**7,5**
T7012T – Composite Materials (Varna) Reinforcement and matrix materials, manufacturing meth-ods. Stress transfer and damage mechanisms in composites. Mi-cro-mech-anism based performance models. Interface properties. Thermal stresses. Inelastic behaviour. Geometrical aspects, statis-tical effects. Prerequisites: Basic knowledge in metallic and polymer materials	**7,5**
T7004T – Surface Engineering (Vuorinen) Contents: Different methods for modification of material surfaces and surface treatment. Atomistic and microstructural description of surfaces together with morphological and surface topographical description of surfaces. The effect of surface energy, surface tension and wetting on the physical and mechanical properties of surfaces. Friction in sliding as well as rolling under dry and lubricated conditions. Different types of wear such as adhesive wear, abrasive wear, surface fatigue, fretting and erosive wear. Impact of corrosion on wear processes. Different methods for characterisation of surfaces especially from a tribological point of view. Surface engineering for friction and wear control. Prerequisites T0005T, F0019T: Solid states Physics for M, T0003T: Materials Technology & Materials Selection and T7008T or equivalent	**7,5**
T0007T – Materials Selection and Ecodesign (Vuorinen) Methodology for materials selection. Knowledge of envi-ronmental problems, energy consumption and materials selection in relation to different production methods during the lifecycle of products. Methods for the design of processes and products to achieve a sustainable develop-ment are enlightened. The engin-eer's responsibility and possibilities to work in an environ-mental-ly conscious way will be shown. The course will train the ability to take environmental considerations in selection, pro-duction and use of materials. Prerequisites: Basic knowledge of materials science and engineering	**7,5**
T7016T – Material Mechanics (Lindgren) The different steps in material modelling are introduced. Thereafter the physical phenomena that cause plastic deformations and the theory of plasticity for deviatoric plasticity are described. Furthermore, common empirical material models and physical based material models for plasticity are outlined. The method that is used by finite element codes to solve these equations is described. Prerequisites: General entry requirements	**7,5**
T7017T – Biocomposites (Oksman) The student will, after the course, has a basic knowledge about biocomposites where the reinforcements or matrix materials are renewable. The goal is that the student will know different raw materials used for biocomposites, know the important properties and processing technologies as well as the use. Further more the student will learn product design for biocomposites, work in a group, make a poster and oral presentation. Prerequisites: General entry requirements	**7,5**
T0018T, Laser Material Processing (Kaplan) The course comprises mainly: Laser theory and optics Interaction of high power laser beams with material Industrial laser processes: cutting, welding, surface treatment and other methods eg. Drilling Industrial laser systems Prerequisites: General entry requirements	**7,5**
T7015T, Advanced. Processing and Cyberlab (Kaplan)	**7,5**

Survey on traditional materials processing techniques (cutting, forming, joining, etc.); Selected examples of advanced processing techniques (laser processing, adhesive bonding, EDM, etching, etc.); Theory and practice of laser welding. Instrument knowledge Mathematical modelling; CyberLab remote experiment technique Application of engineering instruments along with personal skills Mathematical modelling of laser welding; Laser welding laboratory experiments; CyberLab remote laser welding; CyberLab remote microscopy Prerequisites: General entry requirements	
T7009T – Project Work (Joffe) *(Compulsory)* Seminars will be included in the course.	**27**

Institut National Polytechnique de Lorraine (INPL) Ecole Européenne d'Ingénieurs en Génie des Matériaux - Nancy, France	
Courses	**ECTS**
Bibliographic project (Horwat) The student select a project in a list provided at the begining of the semester. The project concerns a material, a class of material, a characterization or synthesis method. The student produces a critical review of the area in close connexion with an specialist of the topic, he or she also presents the project orally.	**3**
Biopolymers and Degradable Polymers (Jonquieres) The degradation impact on the polymer properties. The different mechanisms of physical and chemical degradations (thermal, thermal oxidative, photooxidative, hydrolytic, radiochemical degradations and biodegradation etc.). The different types of stabilisation agents: thermal, photochemical, fungicidal and bactericidal, fireproof stabilisers. Brief overview of the environmental impact of stabilisers. Biopolymers and derivatives: natural rubber, cellulose and its derivatives, starch and related materials, bacterial polyesters and protein-based materials. The strongly debated "photo-biodegradable" hydrocarbon polymers. The principal biodegradable polymers from petrochemical and renewable resources, with a particular focus on poly(lactide) which is the most important industrial example in this category...	**0,5**
Characterisation Methods (Dehmas) Radiation-matter interactions – Scanning electron microscopy (SEM) – electron probe microanalysis (EPMA) – Transmission electron microscopy (TEM) – Energy and wavelength dispersion spectroscopy (EDS, WDS)- Demonstration of the different experimental tools	**3**
Chemical Reaction Engineering (Simonnot) Contents: Energy and mass balance sheet for perfect reactors. Yield optimisation and selectivity (composite reactions). Thermal behaviour of reactors. Elapsed time distribution. Modelling. Prerequisites: Chemical reaction elements and basic thermodynamics.	**3**
Composite Materials with Polymeric Matrix (Etienne) The combination in a composite material of a continuous matrix and reinforcements produces synergy between the properties of the components. The aim of this course is threefold, namely : a) an introduction to the different kinds of composites (from the currently used to the high performance ones), the preparation and synthesis of the polymeric matrices, b) processing and making of composites and finally c) the properties of the composites that are processed. This way, the student receives the fundamentals that are necessary to design and develop these materials with well specified and controlled properties. Contents: An overview of composite materials, Synthesis of polymeric matrices, Presentation and properties of reinforcements, Mechanisms of matrix/reinforcement adhesion (an introduction), Physical and mechanical properties of composites, Processing methods of composite materials with polymeric matrix, Nano-composites and functional composites (an introduction), Studies of specific cases.- Study of aluminium.	**1,5**
Crystal Structures and Defects (Redjaïmia) Phase diagrams, thermodynamical stability. Global approach to phase transformation, driving forces and kinetics. Phase transformations involving diffusion, homogeneous and heterogeneous nucleation and growth. Diffusionless transformations, martensitic; supersaturated solid solutions; amorphous materials.	**5**
Ecodesign (Simonnot) The objective of ecodesign is the integration of the environment at each step of the development of a product (as well as cost, quality, security). The methodology consists in quantifying the environmental impacts at every step of the life cycle of a product or a process or a service, from the extraction of the raw materials to the end of life. Life cycle analysis (LCA) is the most common methodology. All the inlet and outlet mass and energy fluxes are quantified and the results are given in terms of environmental impacts e.g. non renewable raw material and energy consumption, global change, impact on human health, on ecosystems etc. The goal of these lectures is to define the notions of sustainable development, environmental management system, eco-design, life cycle analysis. Content: This course is composed of lectures on of an approach of development, environmental management system, eco-design, life cycle analysis, and of a formation to Simapro, which is the main software used in Europe for Life Cycle Analysis.	**2**
Elaboration Processes (Patisson) This course described the methods in process engineering through systemic and phenomenological energetics approaches. Elaboration processes and treatments are analysized and up to date mathematical models for their description are presented. The models relies on transport and chemical reaction laws.	**3**
Formulation of Polymer Blends (Six) This lecture will show that blending two commercial polymers can ensure the development of new polymeric materials, as it also the case for polymerization or copolymerization methods. First, the basis of the thermodynamics of blend will be given, then we will see how important it is to control the adhesion between the main two phases to improve the properties of the blend. Content: Homogeneous and heterogeneous polymeric blends, Thermodynamics of polymeric blend, Case of totally or partially miscible blends, Notion of spinodal and bimodal curves, blends characterized by LCST or UCST, The various morphologies of polymeric blends and resources to study them, Case of heterogeneous polymeric blends: How to improve adhesion between the two main phases?, Case of blends containing one or two copolymers.	**0,5**
Functional Polymers (Etienne) Polymers as biomaterials, Definition and history of biomaterials, The different properties and applications of biomaterials, Comparison of the different materials, Economical aspects. Specific examples: Complete hip prosthesese, coronary endoprostheses	**1**
Granular Solids and Porous Media (Barth)	**3**

Contents: (1) Populations of solid particles: their characterization as to size, shape and their distribution, their adjustment via such operations as classification and milling, (2) Dry granular systems : stability, flow, mixing and segregation, pressing, (3) Colloïdal systems : effect of dispersing medium properties upon particle – particle interactions ; DLVO theory of suspension stabilization. Brief account of spherical stabilization. (3) Fixed porous media : capillary condensation, DARCY law for single phase gas or fluid flow. Prerequisites: Fundamentals of physical chemistry. Statistical analysis	
Inorganic Materials Phase Transformation (Redjaïmia) Heat treatments, thermo-mechanical and thermo-chemical treatments. Illustrations with dual-phase steels, stainless steels, building steels, tool steels. Nickel and cobalt based superalloys. Titanium, aluminium and copper alloys. Microcrystalline, amorphous and intermetallic alloys. Surface hardening. Prerequisites: Fundamentals of kinetics and thermodynamics.	**5**
Laboratory: Polymers (Etienne) Contents: Physical properties of polymers: viscoelasticity, mechanical tests (tensile test and impact test). Calorimetric and thermal expansion analysis (DSC). Crystallisation and melting study through optical polarising microscopy. Elastic constant measurements (ultrasonics). Prerequisites: Illustrations of topics studied during the courses: "Polymer Physics" and "Macromolecular Chemistry".	**2**
Macromolecular Chemistry (Six) Contents: Chain polymerizations (radical and ionic polymerizations will be discussed in details). -Polycondensation. – Copolymerization – Introduction to physico-chemistry of polymer solutions – Determination of the molecular weights. Prerequisites: Knowledge of the reactivity of organic functions involved in polymer synthesis (reactivity of double bonds, condensation reactions…)	**4**
Materials Characterization (Bauer) This course details the physical penomena at the basis and uses of the following characterization methods: Scattering, microprobe analysis, X absorption and related spectroscopies, scanning and transmission electron microscopy, energy dispersive / energy-loss spectroscopies, resonance spectrometries (NMR, ESR, Mössbauer), infra-red and Raman spectroscopies. Prerequisites: Atomic structure, crystallography, Fourier's transform.	**1,5**
Materials Degradation: Polymers + Corrosion (Jonquieres/Mathieu) Contents: The impact of degradation on the polymer properties. The different types of polymer degradation: physical, mechanical and chemical ageing. The different mechanisms for chemical ageing: thermal, thermal oxidative, photo-oxydative, hydrolytic, radiochemical degradations and biodegradation etc. The different types of stabilisation agents: thermal stabilisers, photochemical stabilisers, fungicidal and bactericidal stabilisers, fireproof stabilisers. Brief overview of the environmental impact of stabilisers. Corrosion reaction thermodynamics: pH-potential diagrams, corrosion diagrams –Kinetic mechanisms for the aqueous corrosion of metals: charge transfer, diffusion – Determination of corrosion rates: Tafel plots, Evan's diagram, Rp measurements, Fick's law – Main forms of aqueous corrosion (uniform, galvanic, localized…) – Protection against corrosion: cathodic and anodic protections, corrosion inhibitors, conversion treatments, metallic and organic coatings. Prerequisites: Electrochemistry. Pourbaix diagrams.	**2,5**
Materials Mechanics I: Viscoelasticity (Ayadi) Contents: Main mechanical behaviours, Main mechanical tests to identify the materials' mechanical behaviour, Basic notions of the physical mechanisms of deformation, Physical mechanisms of deformation in viscoelastic – plastic materials, Characterisation and modelling of the viscoelastic behaviour, Basic elements on the Physics of the rupture of materials, Various types of damage, Linear elastic mechanics of fractures, Experimental determination of fracture toughness, Elastoplastic mechanics of fractures, Crack growth, Fracture of Glass materials, Finite element analysis. Prerequisites: Elastic theory (strain versus stress). Constitution laws	**4**
Materials Mechanics II: Plasticity (Ayadi) Contents: Basic elements of mechanics and thermodynamics of the continuous media; Basic elements of Tribology and Contact mechanics; Plasticity; Mechanical tests; Finite element analysis.	**4**
Materials Mechanics III: Processing and forming To acquire basic scientific knowledge on plasticity, processing and forming, the tribology and on contact mechanics as well as the links with the physical strain mechanisms and fracture ; useful to solve a problem materials mechanics. To familiarize with plasticity and forming; to seize all the physical and mechanical aspects in order to predict the consequences on the final product (material, shape, risk of fracture or instabilities, residual stresses) and on the tools (effort and power involved). To use an industrial finite elements software to study a concrete engineering problem. Materials aspects are analysed and results and assumptions used in the model are discussed.	**2**
Materials Selection More than 100 000 materials (metals and alloys, polymers, elastomers, glasses, ceramics, hybrids, naturals, foams) are available to the designengineer. Other materials, with new properties, will emerge and will expand the family of materials. From this vast menu, what material or what class of materials, must the Design-Engineer select to meet ever stricter industrial, environmental and even artistic requirements. Without a strategy, without clear criteria, the mission of the Design-Engineer will be most difficult and could lead to the choice of materials whose properties are not the most optimal and whose costs are surely not the best. This course describes the procedure for the selection of materials based on their intrinsic or technical properties, their functions, their shapes, fabrication processes, their life-cycle, their costs. The optimization of these parameters is part of the design criteria. This rather tedious task is facilitated by the development of databases and selection assistance software made available on the market.	**1**
Measurements and Data Interpretation (Besson)	**2**

Practical approach to the metrology techniques related to materials investigation and characterisation. We do not focus on characterisation processes here : the main aim of this laboratory work is to make the students sensitive to the problems relating to measurement (system calibration, sample preparation, etc.) and to the treatment of the investigation systems output data (i.e. statistic tools or signal and image processing tools for data interpretation). Contents: Infrared spectroscopy/UV spectroscopy- Metallography, optical microscopy, image processing – Thermal analysis – Mechanical testing (hardness, resilience) – Data digitising	
Mechanical Behaviour of Composite Materials (Meshaka) constituent materials with significantly different physical or chemical properties and which remain separate and distinct on a macroscopic level within the finished structure. The objective of this course is to study the mechanical behavior of fibre materials, mutilayer materials or sandwich materials.The course is illustrated by different case studies that are treated both in the analytical framework of the two-dimensional Love-Kirchhoff plate theory and by numerical means (Abacus FEM code). The comparison of the 3D and 2D numerical solutions is also made in order to highlight the transverse shear effect. Contents: General information on the composites: fibre materials, multi-layer materials, sandwich materials; Revisions of the basics of the deformable solid mechanics; Determination of the elastic constants of a unidirectional ply; Thermo-hygro-mechanical behavior of laminated plates; Damage and fracture mechanism	**3**
Medical Applications of Polymers (Six) The biomedical applications of polymer are numerous. Each of them requires knowledge in chemistry, physico-chemistry and physical properties of polymers, but also in biology. That's why this course will only introduce the biomedical applications of polymers. You will learn how it is possible to propose a polymeric biomaterial, taking specifications required by the application into account. Contents: Definitions and history of biomaterials. The various properties of biomaterials.Their application fields. Comparison of each material used to produce biomaterials. Economic aspect. Examples : Total hip replacement, stent	**0,5**
Microstructure Formation (Gautier/Bauer-Grosse) Contents: Multi-scale phase transformations - equilibrium diagrams - transformation driving force - nucleation driving force - growth rate.	**3**
Physical Properties of Materials (Bauer) Macroscopic magnetism: B and H fields; demagnetizing field; various types of magnetic behaviour - Microscopic magnetism: NMR principle; ferromagnets – Intermediate level magnetism : domains, Bloch walls, anisotropy – Hard and soft materials - Ferrites - Dielectrics: ferroelectrics ($BaTiO_3$), dielectrics in alternative fields (Debye relaxation, resonances in the infrared and optical range) - Optical absorption and dispersion in glasses – Dielectric breakdown and microstructure (Weibull distribution). A poster session by students on practical applications of these physical properties. Prerequisites: Nearly free electron approach. Molecular orbital theory.	**5**
Plastic Deformation and Microstructures (Jacques) Crystallised materials microstructures. Plastic deformation and hardening mechanisms. Microstructure building. Phase transformations.	**3**
Polymer Physics (Etienne) Introduction to macromolecules. Solid state cohesion (role of energy). Rubber elasticity (role of entropy). Glassy state and liquid-glass transition. Linear visco-elasticity. Semi-crystalline polymers (crystallisation, melting, structure versus properties). Mechanical behaviour at large strains (notions). Prerequisites: Macromolecular chemistry. Fundamentals of physical chemistry.	**5**
Process Engineering (Simonnot) This laboratory work is intended to make the students familiar with pilot factory plants. Prerequisites: Illustrations of topics studied during the courses "Chemical reaction engineering" and "Separation engineering".	**3**
Project Work The project is a preparation to a research work. The student is hosted by a research group and is entrusted a bibliographic work and, after an adaptation phase, conducts simple experiments related to the bibliographic work. The knowledge acquired, and experimental methodology of the student is evaluated by the advisor and by external experts on the basis of a written reports and an oral presentation. This project can be the preliminary part of a master thesis.	**15**
Separation Engineering (Barth) Calculation of the height or length of a column. Emphasis is put on writing down mass balances, heat balances. Sometimes these balance sheets must be linked through a relationship. We describe three units: extraction, distillation and drying. Some technological aspects are developed in the case of extraction columns. Prerequisites: Basic thermodynamical concepts and heat –matter transfer mechanisms.	**2**
Solid State Diffusion (Redjaïmia) The Diffusion Concept First and Second Fick's Laws and Continuity Equation. Mass Conservation. Diffusion Coefficients. Activation Energy. Microscopic Diffusion Mechanisms. Vacancy Diffusion. Interstitial Diffusion. Solutions of the Linear Diffusion Equation. Error Function. Method of Fourier Series. Method of Laplace Transforms. Chemical Diffusion. Kirkendall effect Kirkendall's Diffusion Couple Experiment Significance of Kirkendall Marker Motion. Darken's Analysis of the Interdiffusion Inverse Diffusion (Up-Hill Diffusion). Matano's Geometry and interface. Matano Interface Application of the Boltzmann-Matano Method.Others topics : aspects of Diffusion (Dislocations, Grain Boundaries) Experimental Methods. Prerequisites: Fourier and Laplace transforms. Basic solid state physics.	**4**
Stress Microstructure Relationship (Denis) Stresses-phase transformation analysis - Effect of stresses on phases equilibria, germination, growth - consequences on the mechanical behaviour during phase transformations - case of internal genesis during annealing treatments	**3**
Surface Treatment I: Introduction (Capon)	**3**

Introduction to Vapour phase deposition (F. Capon) : plasma – chemical methods (CVD, PECVD, MOCVD, LACVD, ALD) – Physical methods (Sputtering, Cathodic Arc Evaporation, Pulsed Laser Deposition) – Ion Implantation tribology and surface mechanics (R. Kouitat)	
Surface Treatment II: Advanced (Horwat) Focuses on the energetics of filtered cathodic arc evaporation and magnetron sputtering methods. Describes the latests advances of the methods and impact on the films behaviour.	**3**
Waste and Effluent Recycling (Pineau/Simmonot Introduce students to issues concerning sustainable development and protection of the environment. Examples are chosen in the field of waste and effluents recycling (regulation, process …). Contents: (1) Classification, characterization and sampling of waste, (2) Energy recovery from waste, (3) The business of waste, (4) The ISO 140001 norm, (5) Study of aluminium	**2**