Materials Engineering Degree
Universidad Politécnica de Madrid
E.T.S.I. Caminos, Canales y Puertos

POLITÉCNICA

Exchange Programmes
Courses in English 2011 – 2012
Materials Engineering degree – Technical University of Madrid UPM

The advent of the Bologna Process has caused the reform and adaptation of higher education in Europe. In this context, the Technical University of Madrid UPM (Spain) has introduced a new post-baccalaureate, four-year degree course in Materials Engineering, in which the third year is taught entirely in English.

The course involves a forward-looking curriculum. The students will acquire knowledge of the three main branches in the field of materials: traditional structural materials, functional materials (semi, dielectric, optical conducting and magnetic materials used to create integrated circuits, storage media, sensors and other devices) and biomaterials (materials that interact with biological systems; materials of biological origin; and biomimetics).

With significant media attention focused on biotechnology and nanotechnology, in recent years materials engineering has been propelled to the forefront at many universities. One of the primary objectives of the European Higher Education Area (EHEA) is to open education systems to free movement of students. In this sense, a primary objective for the new degree has been that of enhancing student exchange programmes with other higher education institutions. The second, third and fourth year of the new Degree have been opened to exchange programmes. Moreover, the third year will be taught entirely in English.

Exchange Programmes – Courses offered 2011-2012

- **Courses in English**: 12 subjects, equivalent to 72 ECTS (European Credit Transfer System, 30 ECTS credits equals one full semester academic load), will be offered in English for the academic year 2011-2012. Course programmes and additional information are included in this document.

- **Courses in Spanish**: 14 subjects, equivalent to 72 ECTS, will be offered in Spanish for the academic year 2011-2012. More information: http://www.materiales.upm.es/EP/CoursesES.asp

- **Diploma Project**: Three of the most important Centers for Materials Research in Spain participate in the teaching activities of the Materials Engineering Degree. They offer the possibility of doing a final project in their state-of-the-art facilities:

- *Instituto Madrileño de Estudios Avanzados de Materiales* (IMDEA): Madrid Institute for Advanced Studies of Materials (http://www.materials.imdea.org/)
- *Centro de Tecnología Biomédica* (CTB): Biomedical Technology Center (http://www.ctb.upm.es/)
- *Instituto de Sistemas Optoelectrónicos y Microtecnología* (ISOM): Institute for Systems based on Optoelectronics and Microtechnology (http://www.isom.upm.es/)

Technical University of Madrid – *Universidad Politécnica de Madrid* UPM

The Technical University of Madrid (UPM, *Universidad Politécnica de Madrid*) is the oldest and largest of the Spanish Technical Universities. UPM has more than 3.000 faculty members, around 37.000 undergraduate students, and around 8.000 graduate students.

In the style of the French Grandes Écoles, UPM is made up of 21 Schools dealing with the different areas of technology. Although UPM is a young university, having been founded only in 1971, most of its Schools are over a hundred years old, dating back to the 18th and 19th centuries and existing independently until they were grouped together as UPM. It is not an exaggeration to say that much of the history of Spanish technology for over one and half centuries was written by the Schools of Architecture and Engineering of this university, as for many years some of them were the only Technical Schools in existence in their fields in Spain. Almost all the leading Spanish educators and researchers have been involved with UPM either as students, teachers, or both. More information: www.upm.es

Civil Engineering School – *Escuela Técnica Superior de Ingenieros de Caminos, Canales y Puertos*

The Materials Engineering Degree is taught in the *Escuela Técnica Superior de Ingenieros de Caminos, Canales y Puertos de Madrid*, which was founded in 1802 by Agustín de Bethancourt. Over time, and just like the Ecole de Ponts et Chaussees of Paris (founded forty years later and based on the Spanish School of Civil Engineers), the School became one of the most prestigious centers in Spanish society in the 19th and 20th centuries. It was a training centre for the elite general engineers which had a great influence on the social and political life in Spain in the last two centuries. Renowned luminaries such as Echegaray, La Cierva, Torres-Quevedo, Saavedra, Cerdá, Torroja, Aguirre, Fernández Casado and numerous others who formed part of the technical, industrial and intellectual vanguard of the country for many years all studied at the School.
More information: www.caminos.upm.es

Student life - MADRID

UPM Campus is located in the urban district of Madrid (about fifteen minutes walk from the city center) with a very good public transportation system (Metro Station: Ciudad Universitaria). Madrid is the capital of Spain and the political and financial center of the country. It is a modern city with a vibrant economic and cultural life, and the prime European hub to Latin America. Actually, the current income per capita of the Madrid region is 20% higher than the European Union average. Of some 44 million people living in Spain, close to 6 million live in the region of Madrid. Madrid is home to 13 universities of which 7 are public. UPM is the only public exclusively technical university among them.
More information: www.esmadrid.com

Materials Engineering Degree
Universidad Politécnica de Madrid
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POLITÉCNICA

Courses in English 2011 – 2012

TABLE I. Subjects taught in english in the first semester (September-January)

Subject	ECTS	Topics
MECHANICAL BEHAVIOUR OF MATERIALS III	6	Plasticity. Viscoplasticity
PROPERTIES OF MATERIALS II	6	Magnetic properties. Thermal properties
COMPOSITE MATERIALS	6	Classification. Fabrication. Macro/Micromechanics. Performance in service
NUMERICAL SIMULATION IN MATERIALS SCIENCE AND ENG.	6	Numerical methods. Graphic representation. CAD
OBTENTION OF MATERIALS	6	Extractive metallurgy. Siderurgy. Obtaining of non metallic materials
WORKSHOP ON FUNCTIONAL MATERIALS: STRUCTURE	6	Characterization of semiconductors: Profilometry, SEM, AFM, XRD
BIOMIMETICS	6	Self-assembly. Hierarchical materials. Smart materials. Biosensors

TABLE II. Subjects taught in english in the second semester (February-June)

Subject	ECTS	Topics
QUALITY AND QUALITY MANAGEMENT	6	Components. Systems and Processes. Projects. Standardization. Certification
MECHANICAL BEHAVIOUR OF MATERIALS IV	6	Fracture. Fatigue. Creep. Structural Integrity
NANOTECHNOLOGY	6	Structures. Fabrication. Characterization
SURFACE ENGINEERING	6	Semiconductors. Epitaxy. Doping. Characterization
MATERIALS RECYCLING	6	Environment. Recycling. Recovery. Inerting

* Programmes and additional information on these subjects are included in the next pages.

* Lectures will be given in the mourning, from 9:00 to 14:00. Detailed schedule will be published before the beginning of the semester. There will be no overlapping in the schedules of all subjects in the same semester.

* Average work load for a student in Europe is 30 ECTS/semester

* Spanish courses are available:
http://www.upm.es/institucional/FuturosAlumnos/Movilidad/Lenguas+para+la+internacionalizacion/Area+de+Espa%C3%B1ol

Mechanical Behaviour of Materials III
Theory of plasticity

Subject	Topics	Semester	ECTS*	Lectures
Mechanical Behaviour of Materials III. Theory of plasticity	Plasticity. Viscoplasticity	1 (Sept-Jan)	6	5 h/week

* ECTS (European Credit Transfer and Accumulation System): one credit corresponds to 25-30 hours of student´s work

Programme

1. **Introduction**

Development of the course. Objectives. Program. Bibliography

2. **The tensile test**

Engineering stress-strain. True stress-strain. Máximum load. Stress-strain empirical laws. The Bauschinger effect. The simple compression test**.**

3. **Yield Criteria's.**

Isotropic materials definition.. Yield of metallic materials. Geometrical representation. Tresca and Von Mises Criteria's. Non metallic materials criteria. Coulomb Criterion. Drucker-Prager Criterion. Strain hardening effect.

4. **Constitutive equations**

Introduction. Stress-strain relationship for isotropic materials. Stress-strain relationship for metallic materials. Hill equations. Prandtl-Reuss and Levy-Mises equations. Hencky equations.

5. **Plain strain**

Hypotheses. Plain strain equations. Slip line field. Hencky equations. Velocity distribution. The hodograph.

6. **Viscoplasticity**

Definitions. Creep and relaxation. Logarithmic creep and Andrade. Stress and temperature effects.

7. **Time dependant plasticity**

Strain rate effect. High strain rate constitutive models. High strain rate failure models. Testing at high strain rate.

8. **Pure bending.**

Hypotheses. Elastic moment and plastic moment. Plastic mechanisms.

9. **Plastification of beams**

Analysis of the process. Isostatic and hyperstatic beams. Collapse loads. The extremum principle.

10. **Plastification of plates**

Analysis of the process. The failure lines method. Collapse loads.

11. **Plastification of tubes**

Analysis of the process. Thin wall tubes. Plastification of pipes and spheres.. Instability. Maximum pressure . Thick wall tubes.

Properties of Materials II

Subject	Topics	Semester	ECTS*	Lectures
Properties of Materials II	Magnetic properties. Thermal properties	1 (Sept-Jan)	6	5 h/week

* ECTS (European Credit Transfer and Accumulation System): one credit corresponds to 25-30 hours of student´s work

Programme

Magnetic Properties

1. Diamagnetism and paramagnetism.
2. Ferromagnetism.
3. Antiferromagnetism and ferrimagnetism.
4. Magnetic Anisotropy.
5. Magnetostriction.
6. Influence of temperature.
7. Domains and Hysteresis.
8. Fine Particles and Thin Films.
9. Electron Interactions and Magnetic Structure.
10. Soft Magnetic Materials.
11. Hard Magnetic Materials.
12. Superconductivity

Thermal Properties

13. Thermal properties of Solids.
14. Thermal expansion.
15. Thermal stresses.
16. Thermal conductivity.
17. Lattice Vibrations and Thermal Properties.
18. Lattice heat capacity.
19. Vibrational modes of a 1-D monoatomic lattice.
20. Specific heat of solids.
21. Classical theory of specific heat.
22. Dulong-Petit’s law.
23. Einstein’s theory of specific heat.
24. Debye’s theory of specific heat of solids.

Composite Materials

Subject	Topics	Semester	ECTS*	Lectures
Composite Materials	Classification. Fabrication. Macro/Micromechanics. Performance in service	1 (Sept-Jan)	6	5 h/week

* ECTS (European Credit Transfer and Accumulation System): one credit corresponds to 25-30 hours of student´s work

Programme

1. **Introduction to Composite Materials**
2. **Reinforcements**

Introduction. Reinforcement classification. Natural fibers. Synthetic organic fibers. Synthetic inorganic fibers. Discontinuous reinforcements. Structure, processing and properties.

3. **Selection Criteria for Reinforcements**

Introduction. Thermo-mechanical properties. Chemical compatibility. Thermal stability. Compression strength. Stiffness.

4. **Mechanical Strength of Fibers**

Failure criteria. Mechanical strength of individual fibers. Mechanical strength of tows.

5. **Reinforcement Architecture**

Particles. Short Fibers. Long Fibers: lamina, laminates, fabrics and multidirectional performs.

6. **Matrix materials**

Metallic matrices. Ceramic matrices. Polymeric matrices.

7. **Interphases**

Adhesion mechanisms. Measurement of mechanical strength of interfaces. Properties control.

8. **Metal Matrix Composites**

Typology and applications. Solid and liquid Processing techniques. Secondary Processes.

9. **Ceramic Matrix Composites**

Typology and applications. Powder metallurgy, impregnation and infiltration processing techniques. Carbon/carbon composites: typology, applications and processing techniques.

10. **Polymer Matrix Composites**

Typology and applications. Thermoset and thermoplastic processing techniques.

11. **Constitutive Equations**

Stress-strain relationships in anisotropic elastic solids. Stiffness and compliance matrices. Material Symmetry of orthotropic and transversal isotropic solids.

12. **Lamina Orthotropic Elastic Behavior**

Orthotropic behavior. Plane stress assumptions. Stress-strain relationships in material axes. Stress-strain relationship in arbitrary axes. Elastic problem of an individual lamina.

13. **Lamina Failure Criteria**

Failure criteria definition. Characterization of the mechanical strength of composite materials. Maximum stress criteria. Maximum strain criteria. Tsai-Hill Criteria. Tsai-Wu criteria.

14. **Laminate Theory**

Definition of laminates. Deformation and stress of laminates. Stress resultants. Stiffness matrix of laminates. Equilibrium equations. Type of laminates. Edge effects and interlaminar stresses. Elastic problem of laminates. Failure of laminates. Tubes, beams and plates with laminates.

15. **Elastic Behavior: Continuous Reinforcement**

Voigt, Reuss and generalized models. Longitudinal elastic modulus. Poisson rates. Transversal modulus. Shear modulus. Hygro-thermal coefficients.

16. **Elastic Behavior: Discontinuous Reinforcement**

Spatial distribution of reinforcements. Unidirectional reinforcements. Elastic modulus. Shear lag models. Reinforcements with spatial random orientation.

17. **Electrical and Hygro-Thermal properties**

Coefficients of thermal expansion. Coefficients of hygroscopic expansion. Residual stresses. Electrical and thermal conductivity.

18. **Mechanical Strength: Continuous Reinforcement**

Longitudinal tensile strength. Statistical effects of fiber failure. Longitudinal compression strength. Transversal strength. Shear strength.

19. **Mechanical Strength: Discontinuous Reinforcement**

Unidirectional reinforcement. Elastic fiber and matrix. Elastic fiber and plastic matrix. Statistical effects of fiber failure. Numerical models. Alignment effects. Oriented and random reinforcements.

20. **Fracture of Fiber Reinforced Composite Materials**

Fiber/matrix decohesion. Matrix plastic deformation. Multiple matrix cracking. Fiber fracture. Fiber/matrix reinforcement. Influence of fiber orientation.

21. **Fracture of Particle Reinforced Composite Materials**

Crack-particle interactions. Crack meandering. Dilatational transformations. Stress transmissions at the crack tip. Effect of elastomeric particles.

22. **Creep**

Unidirectional reinforcement: elastoplastic fiber and matrix. Short fiber and particle reinforced composites. Effect of fiber orientation.

23. **Fatigue and Stress Corrosion**

Particle reinforced composites. Unidirectional reinforced composites. Laminates and multidirectional reinforcements. Stress corrosion.

24. **Impact**

Impact tests. Damage by impact. Residual strength after impact.

25. **Mechanical Characterization of Composite Materials**

Tests standards. Tensile, compression, bending, shear and interlaminar tests: geometry, instrumentation, tests procedure and results analysis.

26. **Non Destructive Evaluation**

Quality assessment. Non destructive evaluation objectives. Ultrasonic and acoustic emission. Radiography. Mechanical Vibrations. Thermography.

27. **Joints and Repairs**

Importance of joints. Mechanical and adhesive joints: typology, stress analysis, design criteria and failure mechanisms. Repairs of mechanical and adhesive joints.

Numerical Simulation in Materials Science and Engineering

Subject	Topics	Semester	ECTS*	Lectures
Numerical Simulation	Numerical methods. Graphic representation. CAD	1 (Sept-Jan)	6	5 h/week

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Programme

1. **Introduction**
2. **Numerical Analysis Fundamentals**

Computational methods for linear algebra. Solution of linear systems. Non linear systems: Newton-Raphson method. Methods for integration of ODEs. Monte-Carlo methods

3. **Continuum Mechanical/thermal simulation: The Finite Element method**

Theory, strong and weak formulations. Elements, interpolation, integration. Mesh generation algorithms. Equation assembly and solution. Errors in the FEM. Open source & commercial codes.

4. **Discrete simulation: Molecular mechanics**

Theory. Description of potentials . Molecular dynamics . Molecular statics (0K equilibrium calculations). Kinetic Monte-Carlo. Open source & commercial code.

5. **Other simulation techniques in Material Science**

Computational Fluid dynamics. Dislocation dynamics. Thermodynamic simulations. Simulation of diffusion. Phase field method.

Obtention of Materials

Subject	Topics	Semester	ECTS*	Lectures
Obtention of Materials	Extractive metallurgy. Siderurgy. Obtaining of non metallic materials	1 (Sept-Jan)	6	5 h/week

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Programme

1. **Introduction to the extractive metallurgy**
2. **Physical preparation of ores.**
3. **Thermodinamic principles of metallurgical processes.**
4. **Electrochemical principles for the metallurgical processes.**
5. **Kinetics of metallurgical processes.**
6. **Preparation of raw materials**
7. **Metal extraction by reducing fusion. Oxides fusion**
8. **Steel making**
9. **Metal extraction by oxide reduction. Reduction and conversion of sulfides.**
10. **Metal extraction by volatilization.**
11. **Molten salt electrolysis**
12. **Pyrometallurgical metals refining**
13. **Leaching: Treatment of Leach solutions. Conditioning**
14. **Leaching technologies**
15. **Solid/liquid separation**
16. **Solution purification (I)**

Chemical precipitation. Cementation. Adsorption on activates charcoal. Technology. Case of gold metallurgy.

17. **Solution purification and concentration (II)**

Solvent Exchange and ion Exchange.

18. **Metal recovery.**

Precipitation systems. Crystallization, Hidrolytic and ionic precipitation, reduction.

19. **Electrowinning and electrolytic refining**
20. **Mineral raw materials for ceramic manufacturing.**
21. **Mining, crushing and grinding ores**
22. **Ores concentration and process for the ceramic manufacturing.**
23. **Synthetic raw materials for the ceramic materials manufacturing.**
24. **Raw materials for the obtention of polymers**
25. **Polymerization reactions.**

Workshop on Functional Materials: Structure

Subject	Topics	Semester	ECTS*	Lectures
Workshop on Functional Materials: Structure	Characterization of semiconductors: Profilometry, SEM, AFM, XRD	1 (Sept-Jan)	6	5 h/week

* ECTS (European Credit Transfer and Accumulation System): one credit corresponds to 25-30 hours of student´s work

Programme

Laboratory practical work on the characterization of semiconductors: Profilometry, SEM (Scanning Electron Microscopy), AFM (Atomic Force Microscopy), XRD (X-Ray Diffraction) in the Instituto de Sistemas Optoelectrónicos y Microtecnología (ISOM): Institute for Systems based on Optoelectronics and Microtechnology (http://www.isom.upm.es/)

Biomimetism

Subject	Topics	Semester	ECTS*	Lectures
Biomimetism	Self-assembly. Hierarchical materials. Smart materials. Biosensors	1 (Sept-Jan)	6	5 h/week

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Programme

1. **Introduction**

Biological Materials and Biomaterials

2. **Examples of hierarchical microstructures I: Nacre.**

Mineral phase. Toughening mechanisms. Composition of the organic phase. Sequence of the organic phase. Comparison of sequences.

3. **Examples of hierarchical microstructures II: Bone**

Molecular architecture of collagen. Secondary, tertiary and cuaternary structures. Experimental techniques for microstructural characterization. Atomic interactions. Organization of the mineral phase. Properties of bone. Scaling of properties from microscopic to macroscopic levels.

4. **Hydrophobic interaction and self cleaning surfaces: Lotus**

Hydrophobic interaction and entropy. Contact angle measurements. Origin of hydrophobicity in lotus leaves. Hydration of biomolecules.

5. **Examples of hierarchical microstructures III: Silk**

Composition of silk. Nanocrystals and secondary structure. Interactions and mechanical properties. Elastomeric behaviour.

6. **Examples of hierarchical microstructures IV: antireflective surfaces and cornea**

Origin of the antireflective behaviour in biological systems. Transparency of cornea.

7. **Adhesives**

Chemical adhesives: mussel glue. Comparison with other proteins. Mechanical adhesives: geckos. Mechanical adhesives: Velcro.

8. **Mucus.**

Polysaccharides in aqueous environments. Proteoglycans and glycoproteins. Determination of complex tridimensional structures. Complex fluids.

9. **Self-assembly and hierarchical microstructures**

Sickle cell anemia. Self-assembly of macromolecules. Microscopic description of macromolecules. Thermodynamics of self-assembly.

10. **Biomineralization**

Biologically induced processes. Vesicles. Ionic channels. Biologically controlled processes. Nacre biomineralization. Bone biomineralization. Adsorption and nucleation processes.

11. **Energy production I: Photosynthesis**

Chloroplasts. Molecules involved in photosynthesis. Conversion of electromagnetic radiation in chemical energy.

12. **Energy production II: Oxidative phosphorilation**

Mitochondria. Molecules involved in oxidative phosphorilation. Energy generation in euchariotic cells.

13. **Repairing**

Cell communication. Tissue regeneration. Mechanism of bone repairement. Spider silk recovery.

14. **Locomotion mechanisms in animals**

Swimming. Flight.

15. **Deployable structures**

Locust intersegmental membrane. Importante of viscoelastic behaviour.

16. **Cellular nanomachines.**

Dynein. Kinesin. Work generation and conformational modifications. Experimental characterization of macromolecular dynamics.

17. **Muscles**

Muscular contractility. Signal transmisión. Actin and myosin. Conversion of chemical energy into work.

18. **Nerve impulse**

Membrane potentials. Generation and transmisión of nerve impulses. Ionic transport.

19. **Sensors**

Ionic sensors. Mechanism of vision.

Quality and Project Management

Subject	Topics	Semester	ECTS*	Lectures
Quality and Project Management	Components. Systems and Processes. Projects. Standardization. Certification	2 (Feb-June)	6	5 h/week

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Programme

Quality and Quality Management

1. Concepts and definitions of quality
2. Evolution of the concept and quality models
3. Quality and Income
4. Quality costs
5. Policy and quality objectives
6. Quality Planning
7. Management of human activity
8. ISO system of quality management
9. Basic principles of system quality management
10. The quality system certification
11. The EFQM Model
12. 6 Sigma Methodology
13. Quality and sustainability
14. Quality, interest groups and social responsibility
15. Analysis and resolution of cases

Project Management

16. Introduction to Engineering Project

Concepts. Definitions. Types of Projects. Project Life Cycle

17. Preliminary Project and conditions

Previous Studies. Project feasibility. Market research. Legislation.

18. Defining Project Scope

Approval of the investment. Importance of the scope and content. Objectives and major requirements. Project breakdown structure (EDP)

19. Temporary Programming

Study of programming. CPM and PERT methods. Networks. Basics: Slack, margin, critical path. Precedence diagram. Resource allocation and leveling

20. Resources project

Organizational. Distribution of work. Coordination. Functions.

21. Project Budget

Types of cost estimates for the project. Contingencies and supplies. Importance of time in the project. Relationship between cost and time. Budget and its importance.

Mechanical Behaviour of Materials IV
Fracture Mechanics

Subject	Topics	Semester	ECTS*	Lectures
Mechanical Behaviour of Materials IV. Fracture Mechanics	Fracture. Fatigue. Creep. Structural Integrity	2 (Feb-June)	6	5 h/week

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Programme

1. **Example. Introduction**

Differences between plastic instability and fracture. Elastic energy and complementary energy. Energy balance in crack growth. Crack growth resistance, R. Energy available for crack growth, G.

2. **Computation of the energy available for fracture G (I)**

Computation of G in bidimensional linear elastic problems.

3. **Computation of the energy available for fracture G (II)**

Nonlinear elasticity: the Rice J-integral. The experimental determination of G.

4. **Measurement of the resistance to fracture R (I)**

Measurement of resistance to crack growth: phenomenological factors. Direct measurement of R. Measurement based on the force-displacement curve.

5. **Measurement of the resistance to fracture R (II)**

ASTM-E813 standard test method.

6. **The local approach**

Stress fields and displacements at the crack tip region. Stress intensity factors. Physical interpretation. Relationship between K and G. Fracture criteria expressed in terms of stress intensity factors. Fracture toughness.

7. **Computation of the stress intensity factor K (I)**

Analytical methods for the determination of K.

8. **Computation of stress intensity factor K (II)**

Numerical methods for the determination of K.

9. **Computation of stress intensity factor K (III)**

Experimental methods for the determination of K.

10. **Measurement of the tenacity of fracture K_{Ic} (I)**

Influence of sample dimensions, temperature and the velocity of solicitation in the critical value of K. Normalised tests to measure the fracture toughness K_{Ic}.

11. **Measurement of the fracture toughness K_{Ic} (II)**

ASTM-E399 standard test method.

12. **Crack growth due to fatigue.**

Introduction. Fatigue crack initiation. The crack propagation threshold.

13. **Fatigue with constant amplitude loading**

Fatigue crack propagation under constant amplitude. The Paris equation. The Forman equation. Small cracks. The crack closure effect. The equivalence principle.

14. **Fatigue with variable amplitude loading**

Computation of the fatigue life of an element subjected to constant amplitude loading. The effect of overloading. Crack propagation at variable amplitude. The Palmgren-Miner rule. The equivalent amplitude method. Methods that take into account the load application sequence.

15. **Stress corrosion crack growth**

Introduction. Phenomenology: test duration. Stress corrosion crack propagation. The K_{ISCC} parameter. Test methods. Classification of the aggressive environment. Prevention measures.

16. **Corrosion fatigue crack growth**

Introduction. Phenomenological factors. Crack growth initiation. Crack propagation: the Wei model. Influence of wave frequency and form. Protection methods.

17. **Crack growth due to elastic limit / yield stress**

Comentario [jr1]: No se a lo que se refiere este apartado.

Introduction. Areas in the proximity of the crack. The yield stress zone. Integral C. Characteristic time.

18. **Plastic zone correction of linear elastic fracture mechanics**

Size of the plastic zone. The Irwin approximation. Plastic zone correction factor.

19. **Criteria based on Integral J (I)**

Extension to situations with plasticity. The HRR field.

20. **Criteria based on Integral J (II)**

Computation of J integral. Crack initiation and instability.

21. **The fracture diagram method (1)**

The Dugdale model. The R6 method.

22. **The fracture diagram method (2)**

The EPRI method.

POLITÉCNICA

NANOTECHNOLOGY

Subject	Topics	Semester	ECTS*	Lectures
Nanotechnology	Structures. Fabrication. Characterization	2 (Feb-June)	6	5 h/week

* ECTS (European Credit Transfer and Accumulation System): one credit corresponds to 25-30 hours of student´s work

Programme

1. Introduction to Nanotechnology
- a. Emerging technologies
- b. Nanoscience and nanotechnology markets and scientific policy
- c. Precursors and historical revision
- d. Scaling laws
- e. Basics of QM

2. Nanomaterials and Nanostructures
- a. Bondings and crystals
- b. Inorganic semiconductors
- c. Carbon nanostructures
- d. Nanoparticles and composites
- e. Organic materials

3. Nanotechniques for Fabrication and Characterization (0.8 cr.)
- a. Fabrication and manipulation technologies: deposition, lithography, self-assembling, molecular fabrication, nanomanipu
- b. Characterization techniques:electrical, optical and structural characterization (SEM and TEM, STM and AFM, SOM, nanoindentation)
- c. Image treatment in nanotechnologies

4. Nanoelectronics
- a. Electronic properties of nanomaterials
- b. Applications: logic devices, memories, data transmission, sensors

5. Nanophotonics
- a. Photonic properties of nanomaterials
- b. Applications: emitters, displays, optical tweezers, photonic crystals

6. Nanobiotechnology
- a. Biology at the nanoscale
- b. Nanofluidics
- c. Applications: biomimetics, molecular motors

7. Applications of nanostructures and nanosystems
- a. Automotive and space
- b. Homeland security and defence
- c. Energy and environment
- d. Domotics and textiles
- e. Bioengineering and nanomedicine

Surface Engineering

Subject	Topics	Semester	ECTS*	Lectures
Surface Engineering	Semiconductors. Epitaxy. Doping. Characterization	2 (Feb-June)	6	5 h/week

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Programme

1. **Introduction to semiconductor materials**

Classification of semiconductor materials. Compound semiconductors: alloys. Purity and structural defects in semiconductors. Transfer under the magnetic field: the Gunn Effect. Applications of semiconductor materials. Devices.

2. **Fabrication of semiconductor materials**

Obtaining monocrystalline semiconductor materials. Zone purification systems. The segregation coefficient. Volume growth of monocrystallines. The Czochralski method. The floating zone method. The Bridgman method. Distribution by impurity. The effective segregation coefficient. Preparation of substrates: cutting, polishing and positioning.

3. **Semiconductor material epitaxy**

The concept of epitaxial growth. Liquid-phase epitaxy. Phase diagram. The kinetics of liquid epitaxy: gradual and continuous cooling. Molecular beam epitaxy. Determination of the molecular flow. Knudsen effusion cells: Knudsen's cosine law. Growth conditions: estequiometry. Growth kinetics. Reflection high-energy electron diffraction (RHEED) intensity variations. Ordered alloys. Vapour-phase epitaxy: silicon as a case study. Reaction and mass transfer limitations. Comparing epitaxial methods.

4. **Doping techniques in semiconductor materials**

Diffusion doping: Fick's laws. Interstitial and subtitutional diffusion. Finite- and infinite-source diffusion. Diffusion profiles. Intrinsic and extrinsic diffusion. Diffusion masks. Ionic implantation. Braking factors. Implantation profiles. Channelling effects in ion implantation. Damage caused by implantation and overheating. Implantation masks.

5. **Oxidation and deposition processes of insulating materials**

Thermal oxidation of silicon. Properties of SiO_2. Thermal oxidation kinetics. Reaction and diffusion limitations. Thermal oxidation at low and high pressure. Redistribution of dopants during thermal oxidation. Thermal oxidation techniques. Obtaining SiO_2 and Si_3N_4 through chemical deposition in the vapour phase (chemical vapour deposition, CVD). CVD processes activated (plasma, UV, laser).

6. **Metallisation, chemical attack and photolithography techniques**

Vacuum evaporation (joule and electronic gun). Calculation and measurement of metalisation thickness. Cathode pulverisation. AC and DC magnetrons. Wet chemical attacks: isotropy. Dry chemical attacks: selectivity and anisotropy. Dry attack techniques. Dry attack techniques: plasma etching. Reactive ion etching. Ion beam milling. Thermocompression and ultrasonic welding / bonding. Photolithography: positive and negative photo-resins. Exposure systems: contact and proximity. Printing and projection techniques. The limitations of optical lithography. High-resolution lithography techniques: electrons, ions and X-rays.

7. **Techniques in the characterisation of semiconductor materials**

The Hall Effect. Capacitive techniques. X-ray spectroscopy. Photoluminescence. Scanning and transmission electron microscopy. Atomic force microscopy. Secondary ion spectroscopy. Ellipsometry and reflectance.

8. **Low dimensional structures. High frequency engineering.**

Homounions and heterounions. Band-offset. Deformations in multilayer semiconductor structures. Compressive and tensile strain. Strain relaxation. Critical thickness. Quantum wells. Density of bidimensional status. Ordered alloys and supernetworks. Modulation doping. High electron mobility transistor (HEMT) structures. The effect of confinement and strain. Device applications.

Materials Recycling

Subject	Topics	Semester	ECTS*	Lectures
Materials Recycling	Environment. Recycling. Recovery. Inerting	2 (Feb-June)	6	5 h/week

* ECTS (European Credit Transfer and Accumulation System): one credit corresponds to 25-30 hours of student´s work

Programme

1. **Recovery and Recycling**

Limited and non-recoverable raw materials; Energy Savings ; The external dependency; Environment; Problems and limitations of the primary metallurgy; The products; The Minor metals; Processes design and recovery.

2. **Life cycle.**

Basic ideas; Elementary scheme of the cycle and Phases and Sequences on ferrous scrap, non ferrous Metals, Minor Metals, Electronic Scrap.

3. **Chain of value and recycling process**

Model of the value chain; Ecological design; Resources and recycling sistems; Sustainable production; Sustainable consumption.

4. **Recycling sectors.**

Industrial Recycling; Urban Solid Waste Recycling; Paper, glass and plastics Recycling; Iron, Steel and Aluminum Recycling; Organic Recycling; Electronic Scrap Recycling; Reci. Harmful Materials Recycling; Recycling Economic Factors; Legislation; Innovations

5. **Waste characterization**

Dimensional reduction , Classification and sampling. Gravimetric separation. Heavy Medium. Magnetic, electrostatic and optics separation. Separation by Froth flotation

6. **Pirometallurgy**

Raw material conditioning. Dimensional. Roasting, Calcining and alkaline Fusion. Ellinghan-Richardson Diagram. Oxide reduction, Fusion by matte; Slags, classification and properties; Fluxing agents; Furnaces and processes. Fusion by matte. Ingraham Kellog Diagram . Slags classification and properties. Pirometallurgy refining and igneous electrolysis (molten salts)

7. **Hydrometallurgy**

General principles. Diagram of Pourbaix. Leaching, digestion. Solid-liquid separation.

8. **Electrolyte purification.**

Cementation, Chemical precipitation ,solvent extraction, ion exchange an adsorption on activated charcoal. Reductión an metal precipitation by physic, chemical or electrochemical methods.

9. **Non metals recycling**

Paper and plastic recycling. Glass, fiber glass, construction waste recycling. Asphalts, tires and rubber recycling. Mineral oils and lubricant recycling. Urban solids and waters waste recycling, sludges treatment.Biochar. Incineration and supercritical oxidation of organic waste.

10. **Metallic materials recycling: fferrous materials**

Ferrous materials recycling.Raw materials preparation, processes and applications.

11. **Non-ferrous materials: base metals**

Aluminum recycling. Raw materials, Preparation , processes and applications. Secondary metallurgy of copper. Raw materials, rich scrap irons and alloys; Poor scrap irons and alloys; Processes (Shaft Furnaces, rotative fournaces, converter, anodes fournace,secondary electrorefine). Zinc, Lead and antimony secondary metallurgy. Preparation of the raw materials, processes and applications.

12. **Minor metals**

Secondary metallurgy ofcadmium, cobalt and chromium. Raw Materials preparation , processes and applications. Secondary metallurgy oftin, manganese and molybdenum. Raw Materials preparation , processes and applications. Secondary metallurgy of nickel, titanium and wolfram.Raw materials preparation, processes and applications. Secondary metallurgy of precious metals:gold, silver and platinum. Electronic scrap recovery. Raw Materials preparation, processes and applications.

13. **Harmful metals**

Secondary metallurgy of other harmful metals: mercury and arsenic. Raw materials preparation, processes and applications. Secondary metallurgy ofLithium and Barium. Preparation of the raw materials, processes and applications. Secondary metallurgy of beryllium and asbests . Raw materials preparation, processes and applications. Secondary metallurgy of americium and nickel compounds.Rraw materials preparation, processes and applications.

14. **Treatment of specific materials**

Recycling of Halogenated compounds, Fluorocarbons and Tricloroetylene. Batteries and toner recycling. Recycling of cables and tins (containers). Recycling of Boats, railroads and aviation. Recycling of scrap and military waste. Recycling of radioactive materials. Recycling of composites and ceramics. Recycling of nanomaterials and emergent materials. Dumps disposition of waste . Methodology and Legislation. Treatment of liquid and gaseous pollution. Applicable EU normative. Introduction to simulation of metallurgical plants. Introduction to the computer science packages UMBERTO, USIMPACand METSIM-1. Introduction to the computer science packages UMBERTO, USIMPAC and METSIM- 2. Introduction to the computer science packages UMBERTO, USIMPAC and METSIM- 3.

15. **Presentation of project term.**