Course guide
240751 - 240751 - Science and Technology of Materials

Last modified: 16/05/2023

Unit in charge: Barcelona School of Industrial Engineering
Teaching unit: 702 - CEM - Department of Materials Science and Engineering.

Degree: BACHELOR'S DEGREE IN INDUSTRIAL TECHNOLOGIES AND ECONOMIC ANALYSIS (Syllabus 2018). (Compulsory subject).

Academic year: 2023 **ECTS Credits:** 6.0 **Languages:** English

LECTURER

Coordinating lecturer: Alcala Cabrelles, Jorge

Others:

PRIOR SKILLS

Basic knowledge of density calculations in cubic crystals
Basic knowledge of cubic and hexagonal crystal structures including atomic packing factor calculations.

TEACHING METHODOLOGY

Master classes, video recordings.

LEARNING OBJECTIVES OF THE SUBJECT

To gain a basic knowledge of metallic, ceramic and polymeric materials.
To comprehend the interrelationship between microstructure and mechanical properties. Mechanical property tailoring.
To understand crystalline defects and microstructural development of metals.
To gain basic knowledge of the mechanical behavior of materials and associated testing procedures.
To use phase diagrams in understanding microstructural development of metals and ceramics.
Basic material processing routes.

STUDY LOAD

Type	Hours	Percentage
Hours large group	54,0	36.00
Hours small group	6,0	4.00
Self study	90,0	60.00

Total learning time: 150 h

CONTENTS

Introduction

Description:
Material families and bondings

Specific objectives:
Ionic, metallic and secondary bondings. Electronegativity calculation.
Atomic bonding, bonding energies and basic knowledge of atomic potentials.
Relationship between the bonding energy, the elastic stiffness and the melting temperature.
Intensive vs. extensive material properties.

Full-or-part-time: 1h 30m
Theory classes: 1h 30m

Crystalline structures in metals and ceramics

Description:
Basic understanding of crystalline structures in metals and ceramics. Crystalline vs amorphous structures

Specific objectives:
Different face-centered cubic (FCC), body-centered cubic (BCC) and hexagonal closed-packed (HCP) structures in metals.
Miller indices for planes and directions in the cubic system. Normality rule.
Atomic packing in FCC, BCC and HCP structures. Atomic packing factors.
Density and planar density calculations.
Structures of ionic crystals. Cation to anion ratio and the resulting constructive units.
Silicate structures
Glass transition vs. melting temperature
Glass modifiers
Viscosity vs. density plots and their use in glass processing.

Full-or-part-time: 4h
Theory classes: 4h

Crystalline defects

Description:
Vacancies, dislocations, grain boundaries and free surfaces

Specific objectives:
Point defects (Vacancies and self-interstitials). Maxwell-Boltzman statistics and Arrhenius-type relations.
Vacancy density calculations and thermal-independent activation energies.
Formation of solid solutions. Substitutional solutions and the Hume-Rothery rules. Intersticial solid solutions.
Tetrahedral and octahedral sites in FCC and BCC cells.
Dislocations: Screw vs edge dislocations. Burgers and dislocation line vectors. Dislocation loops. Calculation of the burgers vector.
Glide plane and glide directions. Energy of a dislocation.
Stacking faults and twins: Stacking fault formation and stacking fault energies in pure metals. Twin formation through stacking fault emission in FCC crystals. Transformation of an FCC to and HCP crystal. Habit planes and twin growth directions. Energy of twin boundaries
Grain boundaries: Low-angle grain boundaries and the Read-Shockley model. Generic grain boundaries, misorientation angle and grain boundary energy.
Thermally-activated grain growth and grain growth kinetics. Apex angles in grain boundaries.
Free surfaces and atomistic descriptions. Free surface energy.

Full-or-part-time: 6h
Theory classes: 6h

Solid state diffusion

Description:
Diffusion laws and atomic flux in materials

Specific objectives:
Interstitial and substitutional (vacancy) diffusion.
First Fick's law. Diffusion coefficient and atomistic connection. Steady-state diffusion.
Influence of crystal structure, density and melting temperature on diffusion.
Second Fick's law and non-steady state diffusion.
Characteristic mathematical solutions for non-steady state diffusion.

Full-or-part-time: 3h
Theory classes: 3h

Phase diagrams and microstructures of metallic alloys

Description:
Introduction to binary phase diagrams and their use in predicting microstructures of key metallic materials and alloys.

Specific objectives:
Introduction. Binary isomorphic phase diagram. Lever rule.
Eutectic diagram and non-equilibrium solidification. Dendrite formation in cast metals.
Allotropic transformations.
Peritectic, peritectoid and eutectoid reactions.
Phase diagrams in steels, aluminum alloys, brass, bronze. Microstuctural features.
Martensitic transformations in steels: General features. Bain transformation. Twin and dislocation martensites. Invariant line vs invariant plane theories. Characteristic temperatures in martensitic transformations. Bainite formation. Martensitic vs bainitic structures.

Full-or-part-time: 10h
Theory classes: 10h

Polymers

Description:
Introduction to polymeric materials. Thermoplastics, thermosets and elastomers

Specific objectives:
Monomers and repeat units. Polymeric chains, mean molecular weight.
Copolymers.
Polymer reactions and polymerization methods.
Branched, cross-linked and network polymers.
Polymer crystallinity and defects.
Glass transition and melting temperatures in polymers.
States of macromolecular aggregation.

Full-or-part-time: 4h
Theory classes: 4h

Mechanical behavior of Materials

Description:
Elastic and plastic responses of metals, ceramics and polymers

Specific objectives:
Elasticity in metals and ceramics. Rubber elasticity
Plasticity in metals. The stress-strain curve and its measurement. Associated mechanical properties.
Fundamentals of plasticity in metals: Dislocation glide and slip systems in BCC, FCC and HCP crystals. The critical resolved shear stress and the Schmid law.
Strain hardening and dislocation interactions.
Hardness measurements. Correlation between hardness and the uniaxial stress-strain curve.
Strengthening mechanisms in metals: Solid solution strengthening. Precipitation hardening: the case of Al-Cu and Nickel-based superalloys. Grain boundary strengthening. Nanostructured materials and the inverse Hall-Petch relation.
Microstructural tailoring of metals and the prediction of the yield strength in engineering microstructures. Mechanical properties of steels
Plastic deformation in materials processing.
Fracture and fatigue in metals.
Creep and creep mechanisms in metals.
Mechanical properties of polymeric materials.
Elastic properties of composite materials. Microstructure of metal matrix composites. Ceramic composites and polymeric composites.

Full-or-part-time: 12h
Theory classes: 12h

GRADING SYSTEM

One intermediate examen (E1) and one final exam. The final exam is comprised of three tests: The first is a theory examen (T), the second is a numerical exam comprising a set of problems (P), the third is a laboratory exam based on the laboratory activities of the course (L).

If the grade of the final exam is higher than that of the intermediate exam, then the final grade, FG, is obtained as:
FG = 0.60*T+0.25*P+0.15*L

If the grade of the final exam is smaller than that of the partial exam, then the final grade, FG, is obtained as:
FG= 0.35*E1+0.35*T+0.15*P+0.15*L