Course guide
295702 - PCO - Plastics and Composites

Last modified: 02/10/2025

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

Degree: BACHELOR'S DEGREE IN MATERIALS ENGINEERING (Syllabus 2010). (Compulsory subject).

Academic year: 2025 **ECTS Credits:** 6.0 **Languages:** Catalan, Spanish

LECTURER

Coordinating lecturer: ORLANDO ONOFRE SANTANA PEREZ

Others: Primer quadrimestre:
TOBIAS MARTIN ABT - Grup: M11, Grup: M12, Grup: M13
NICOLAS CANDAU - Grup: M11, Grup: M12
JAVIER GÓMEZ MONTERDE - Grup: M11, Grup: M12
NOEL LEÓN ALBITER - Grup: M11, Grup: M12, Grup: M13
LEANDRO ISIDRO MARTÍNEZ OROZCO - Grup: M11, Grup: M12, Grup: M13
ROSE MARY RITA MICHELL URIBE - Grup: M11, Grup: M12
ORLANDO ONOFRE SANTANA PEREZ - Grup: M11, Grup: M12

REQUIREMENTS

STRUCTURE AND CHARACTERIZATION OF MATERIALS - Pre-requisite
FUNDAMENTALS OF POLYMERS - Prerequisite
MECHANICAL PROPERTIES OF MATERIALS - Prerequisite.

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
1. Knowledge of science, technology and materials' chemistry fundaments. Understanding the relation between microstructure, synthesis or processing and materials' properties.
2. Knowledge and application of materials' technology in the following fields: production, transformation, processing, selection, control, maintenance, recycling, and storage of any type of materials.
3. Knowledge and capacities to evaluate security, durability, and structural integrity of materials and components manufactured with these materials.

Transversal:
06 URI N3. EFFECTIVE USE OF INFORMATI0N RESOURCES - Level 3. Planning and using the information necessary for an academic assignment (a final thesis, for example) based on a critical appraisal of the information resources used.

TEACHING METHODOLOGY

During the course there will be three types of sessions: theory, problems or prcactical cases, and laboratory practices. In addition autonomous learning to relate knowledge acquired in practices with theoretical fundaments. Two exams will take place.

LEARNING OBJECTIVES OF THE SUBJECT

The objective is that the student acquires knowledge on the structure and its relation with physical and mechanical properties of polymeric materials and composite.

STUDY LOAD

Type	Hours	Percentage
Self study	90,0	60.00
Hours small group	10,0	6.67
Hours large group	50,0	33.33

Total learning time: 150 h

CONTENTS

SUBJECT 1. Structure and classification of polymeric materials

Description:
Aspects on evaluation and bibliography of the course.
Brief history of polymer science and technology.
Technological importance of polymeric materials.
Idealization of the polymer chain, preliminary definitions.
Concept of molecular relaxation time.
Configuration and conformation of the chains: isomerisms, molecular architecture, chain mobility.
Classification based on thermomechanical behavior: thermoplastics, thermosets and elastomers.
Classification based on consumption: "Comodities", Engineering and special applications.

Specific objectives:
Global objective of the subject:
Understand the evolution, structure, and classification of polymeric materials, as well as the basic concepts of the polymer chain, to comprehend their behavior and technological applications.

Specific objectives:

- Analyze the historical evolution of polymer science and technology and its impact on modern society.
- Assess the technological importance and current use of polymeric materials in various industries.
- Recognize the fundamental concepts related to the idealization of the polymer chain and preliminary definitions (review).
- Explain the concept of molecular relaxation time and its relevance to polymer behavior.
- Identify and describe the configurations and conformations of polymer chains, including isomerisms, molecular architecture, and chain mobility.
- Differentiate between homopolymers and copolymers based on their composition, i.e., molecular architecture.
- Classify polymers according to their thermomechanical behavior: thermoplastics, thermosets, and elastomers.
- Categorize polymeric materials according to their use and consumption: commodities, engineering, and special applications.

Related activities:
Midterm exam 1

Related competencies :
CE9. Knowledge of science, technology and materials' chemistry fundaments. Understanding the relation between microstructure, synthesis or processing and materials' properties.
CEM5. Knowledge and application of materials' technology in the following fields: production, transformation, processing, selection, control, maintenance, recycling, and storage of any type of materials.
CEM7. Knowledge and capacities to evaluate security, durability, and structural integrity of materials and components manufactured with these materials.

Full-or-part-time: 7h 30m
Theory classes: 3h
Self study : 4h 30m

SUBJECT 2: Solubility and determination of chains dimensions

Description:
Solubility in polymers: good, poor solvent. Condition "teta" of a solvent. Solubility parameters and solvent selection.
Statistical coil and free volume theory.
Characteristic ratio and radius of rotation.
Distribution of molecular masses and average molecular masses: technological implications (review).

Specific objectives:
Global objective of the subject:
Understand the principles of solubility and the structural dimensions of polymer chains to analyze their behavior and properties in different environments.
Specific objectives:
- Explain the concepts of polymer solubility, differentiating between good and poor solvents, and understand the "theta" condition of a solvent.
- Identify and apply solubility parameters for the proper selection of solvents in polymer systems.
- Describe the concept of the statistical coil and understand the free volume theory in the context of polymer chains.
- Relate the polymer chain characteristic ratio to the radius of gyration and its significance in structural analysis.
- Review the concepts of molecular weight distribution and the types of average molecular weights determined, as well as their technological implications in polymer behavior.

Related activities:
Group Activity 1: Selecting Solvents or Liquid Additives for a Formulation.
Midterm Exam 1

Related competencies :
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Full-or-part-time: 7h 30m
Theory classes: 3h
Self study : 4h 30m

TOPIC 3: Introduction to rheological behavior of polymeri melts

Description:
Classification of shear rheological behavior of polymeric fluids.
Shear rheological curves.
Structure-rheological properties relationship: Molecular mass, molecular mass distribution, molecular architecture.
Melt flow index: gravimetric and volumetric

Specific objectives:
Global objective of the subjetc:
Understand the shear rheological behavior of polymeric fluids and its relationship with molecular structure to predict and control their properties in industrial processes.
Specific objectives:
- Classify the different shear rheological behaviors of polymeric fluids.
- Interpret shear rheological curves and their significance in analyzing polymer behavior.
- Analyze the relationship between molecular structure and rheological properties, considering the effects of molecular weight, distribution, and architecture.
- Understand and apply the concepts of gravimetric and volumetric melt flow index in rheological characterization of polymers.

Related activities:
Laboratory 1: Melt flow index determination (MFI y MVR)
Midterm exam 1.

Related competencies :
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Full-or-part-time: 11h 15m
Theory classes: 4h 30m
Self study : 6h 45m

TOPIC 4: Thermal transitions and states of aggregation

Description:
Glass transition (Tg).
Melting temperature (Tm).
States of aggregation as a function of temperature.
Rubber elasticity (Rubery state)
Techniques for determining transition temperatures:
- Differential scanning calorimetry (DSC.
- Thermomechanical analysis (TMA).
- Softening temperatures: HDT and VICAT

Specific objectives:
Global objective of the subject:
Understand the thermal transitions and aggregation states of polymeric materials, as well as the techniques to determine transition temperatures, to interpret and control their thermal and mechanical properties.
Specifics objectives:
- Explain the concepts of glass transition (Tg), melting temperature (Tm), and crystallization temperature (Tc).
- Analyze the enthalpic relaxation phenomenon and its relation to the glass transition: effect of physical aging.
- Describe the aggregation states of polymers as a function of temperature, including the rubbery state and elasticity of rubber.
- Know and apply thermal characterization techniques such as differential scanning calorimetry (DSC) and thermomechanical analysis (TMA).
- Interpret the heat deflection temperature (HDT) and VICAT softening temperature and their relevance in the thermal evaluation of polymeric materials.

Related activities:
Laboratory 2: Differential scanning calorimetry (DSC) applied to polymers.
Midterm exam 2.

Related competencies :
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Full-or-part-time: 15h
Theory classes: 6h
Self study : 9h

SUBJECT 5: Organization in the Solid State

Description:
To discuss:
Disorder:
- Amorphous polymer as sub-cooled liquid.
- Structural factors that affect the vitreous transition.
- Vitrification as a kinetic process.
- Volumetric relaxation vs. Entálpica relaxation: Physical aging.

Order:
- Crystal structures: Lamela, spherulite, Sheas Kebab, Row nucleated
- Isothermal and non-isothermal crystallization process.
- Factors that affect crystallization ability.
- Melting process in semicristaline polymers.

Specific objectives:
Global objective of the topic:
Understand the structural organization of polymers in the solid state, encompassing both disorder (amorphous) and crystalline structures, and the processes that occur during vitrification, crystallization, and melting.
Specific objectives:
- Explain the behavior of the amorphous polymer as a supercooled liquid and the structural factors affecting the glass transition.
- Analyze vitrification as a kinetic process and differentiate between volumetric and enthalpic relaxation, including the physical aging phenomenon.
- Describe the crystalline structures in polymers, such as lamellae, spherulites, Sheas Kebab nucleated structures, and Keller-machin structures.
- Understand the isothermal and non-isothermal crystallization processes and the factors affecting crystallization ability under both conditions.
- Explain the melting process in semicrystalline polymers.

Related activities:
Midterm exam 2.
Laboratory 2: Crystallization kinetics of polymers

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Full-or-part-time: 22h 30m
Theory classes: 9h
Self study : 13h 30m

TEMA 6: Relación estructura-comportamiento mecánico

Description:
Stress-strain curves in polymers: Engineering, true, and intrinsic.
Phenomenology of the deformation process in polymers: Energetic elasticity, Entropic elasticity (rubber elasticity), Plastic deformation, Strain hardening (Natural Draw Ratio).
Structure-intrinsic mechanical behavior relationship: Effect of molecular mass, state of aggregation, orientation, crystalline texture.
Plastic deformation mechanism in polymers: Shear yielding vs. Crazing.
Ductile-brittle transition in polymers.
Environmental Stress Cracking (ESC).
Consequences of the viscoelastic nature.

Specific objectives:
Global objective of the topic:
Understand the relationship between polymer structure and mechanical behavior to interpret and predict their response under different loading and environmental conditions.
Specific objectives:
- Review the stress-strain curves in polymers: engineering, true, and intrinsic.
- Describe the phenomenology of the deformation process in polymers, including energetic elasticity, entropic elasticity, plastic deformation, and strain hardening (Natural Draw Ratio).
- Analyze the relationship between structure and intrinsic mechanical behavior, considering the effects of molecular weight, aggregation state, orientation, and crystalline texture.
- Explain the plastic deformation mechanisms in polymers: shear yielding and crazing.
- Understand the ductile-to-brittle transition in polymers and the phenomenon of Environmental Stress Cracking (ESC).
- Evaluate the consequences of viscoelastic nature on the mechanical behavior of polymers.

Related activities:
Laboratory 4: Thermal treatments in polymers and their effect on mechanical properties
Midterm exam 3.

Full-or-part-time: 22h 30m
Theory classes: 9h
Self study : 13h 30m

TOPIC 7: Heterogeneous polimers: An introduction.

Description:
Definition of "Heterogeneous Polymers": Polymer Blends, Microcellular Polymers (Foams), Composites.
History and Technological Importance of Composites - Classification. Applications.
Matrices. Interfaces and compatibilization. Non-organic second Phases: Microfillers, Nanofillers. Interfaces. Critical Parameters.
Prediction of Mechanical Behavior of Fiber Composites: Elasticity - Tensile Strength. Micromechanical Models. Concepts of critical length and volume of fiber.

Specific objectives:
Global objective of the topic:
Understand the fundamentals, types, and applications of heterogeneous polymers, highlighting the structure and characteristics of composites, as well as predicting their mechanical behavior.
Specific objectives:
- Define heterogeneous polymers, including immiscible blends, microcellular polymers, block copolymers, and composites.
- Know the history, technological importance, and classification of composites, along with their main applications.
- Describe matrices, interfaces, and the compatibilization process, as well as inorganic secondary phases (microfillers and nanofillers) and their critical parameters.
- Explain the prediction of mechanical behavior of fiber-reinforced composites, addressing elasticity, tensile strength, and micromechanical models.
- Understand the concepts of critical fiber length and critical fiber volume in composite mechanics.

Related activities:
Midterm exam 3.

Related competencies :
CE9. Knowledge of science, technology and materials' chemistry fundaments. Understanding the relation between microstructure, synthesis or processing and materials' properties.
CEM5. Knowledge and application of materials' technology in the following fields: production, transformation, processing, selection, control, maintenance, recycling, and storage of any type of materials.
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Full-or-part-time: 15h
Theory classes: 6h
Self study : 9h

GRADING SYSTEM

3 partial exams (NPP-1; NPP-2 and NPP-3) + Continuous evaluation (NEC).

All evaluations will be on a scale of 10. IMPORTANT: ALL EVALUATION ITEMS ARE MANDATORY IN ORDER TO PASS THE SUBJECT.

The final grade (NF) will be calculated from the following expression:

NF = 0.7NTory + 0.3 NEC (Continuous Assessment)

NEC: average of group activities (homework/lab reports, a total of 5). In the case of laboratories, la mark by session will be: 70% report + 30% individual pre-laboratory test.

NTheory = average of the 3 partial tests

In case of NTheory < 4, a final exam must be presented. In this case, the "new" Ntheory to be considered for the calculation of the Final Grade (NF, according to the initial equation) of the subject:
NTheory= 0.3*(Average Partial Tests) + 0.7*EF

EXAMINATION RULES.

The partial exams (ExPr) will be done within the schedule of the subject. No notes, unless instructed to do so by the teacher. They will have a maximum duration of 75 min.
Laboratory reports will be presented in groups of up to 3 students one week after the session. In the first 15 minutes there will be an individual pre-laboratory test.
A template for writing the report will be available at the Digital Campus.

BIBLIOGRAPHY

Basic:
- Hull, Derek. Materiales compuestos. Barcelona: Reverté, 1987. ISBN 8429148396.
- Ehrenstein, G. W. Polymeric materials : structure, properties, applications. Munich [etc.]: Hanser [etc.], cop. 2001. ISBN 3446214615.

Complementary:
- Brydson, J. A. Plastics materials. Oxford: Butterworth-Heinemann, 1999.
- Kinloch, A. J.; Young, Robert J. Fracture behaviour of polymers. London [etc.]: Chapman & Hall, 1995. ISBN 0412540703.
- Ward, Ian Macmillan; Sweeney, John. An Introduction to the mechanical properties of solid polymers. 2nd ed. Chichester: John Wiley & Sons, cop. 2004. ISBN 9780471496267.
- McCrum, N. G; Buckley, C. P.; Bucknall, C. B. Principles of polymer engineering. 2nd ed. Oxford: Oxford University Press, 1997. ISBN 0198565267.
- Michaeli, Walter. Tecnología de los composites/plásticos reforzados. Barcelona: Hanser, 1992. ISBN 8487454046.
- Callister, William D.; Rethwisch, David G. Materials science and engineering : an introduction. 10th edition. Hoboken: John Wiley & Sons, [2020].
- Young, Robert Joseph. Introduction to polymers. 2nd ed. London: Chapman and Hall, 1991. ISBN 0412306409.

RESOURCES

Other resources:
Visual support and animated self-learning material available on the digital campus.
Collection of videos selected from network platforms.