UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Chemistry & Technology of Polymers & Industrial Applications

2526-1-FSM02Q010

Aims

The course aims to explore the preparation and transformation processes of various classes of polymers, with a particular focus on functional polymers and the fabrication of polymer-based materials. Traditional and recent methods and technological processes for improving the chemical, physical, and mechanical properties of polymers, as well as the underlying scientific basis linking these macroscopic properties to fundamental concepts in polymer science, will be covered. Key principles and concepts will be introduced alongside case studies of actual industrial processes.

Knowledge and understanding

By the end of the course, the student will have acquired knowledge on:

• The main classes of polymeric materials, with a specific focus on industrial and functional polymers. This specifically includes polyolefins, polyamides, polyesters such as PET, as well as crosslinked rubber and silicone-based polymers.

• The relation between the molecular properties of macromolecules and the macroscopic properties of polymeric materials, and how the modification or formulation of a polymer can adjust these properties to solve complex technological issues.

• The processes to obtain functional polymeric materials, such as fibers, foams, aerogels, membranes and polymer-based nanocomposites.

• Selected examples and applications of polymeric materials in the industry, with a specific focus on polymer recycling, biopolymers and biomedical applications.

Applying knowledge and understanding

By the end of the course, the student will be able to understand the main classes of polymeric materials, their preparation and properties, and evaluate their technological applications. The student will be able to address problems related to polymer science and contribute to the development of innovative polymeric materials.

Making judgements

The student will be able to critically evaluate the main preparation processes of polymeric materials and their applications in specific industrial and research fields.

Communication skills

The student will be able to communicate the topics covered during the course in a suitable language, using the technical terms relevant to polymer science. He will be able to present and discuss topics of polymer science with

experts in the field.

Learning skills

The student will be able to apply the knowledge acquired during the course to understand and discuss the most recent scientific literature, including patents, regarding polymer science.

Contents

The course encompasses advanced technological processes in the synthesis and transformation of polymers, including new methods of polymer synthesis and introduction to hybrid materials with particular emphasis on preparing and characterising polymer materials endowed with heterogeneous interfaces and new functional properties. The most well-established methods and technological processes to improve their chemical, physical, and mechanical properties will be presented along with recently introduced and state of the art methods, discussing their relative scope in the industry. Several advanced characterization techniques will be presented to elucidate the link between the macroscopic properties and fundamental concepts in polymer science.

Detailed program

• General Concepts

Classification and polymeric sectors: commodities, specialities and engineering polymers.
Polymers as materials: correlation of molecular structure and polymer chain assembly with macroscopic properties additionally affected by processing. Intermolecular interactions and cross-links and their influence on impact and heat resistance properties. Self-assembly of polymer chains and optical properties. Formation of polymeric networks and cross-linked materials.
High-performance polymers: aromatic amides and esters (the case studies of Kevlar, Nomex), polyether ether ketone (PEEK). Polymers of industrial interest: polyurethanes and their properties. Fluoropolymers: structures and properties. Polyimide and related specialty polymers: high-temperature and solvent-resistant polymers for advanced applications.
Synthesis and applications of high-performance fibers and textiles.
Principles for the formation of foams: properties and applications.
Polymeric aerogels: synthesis, properties and applications.
Polymeric membranes: preparation, properties and selected industrial applications.
Advanced polymer synthesis in the solid and in the confined state: replica phenomena and fabrication of innovative polymeric architecture.
Relevant polymeric composites and nanocomposites for industrial applications: integrating hybrid materials, such as modified clays, into polymers to improve mechanical and optical properties. Characterization of the extended interfaces by advanced methods.

• Industrial applications and case studies.

Polymer melt processing: extrusion, injection molding, blow molding, and film casting. Focus on the extrusion process and its applications.
Processing parameters, including pretreatment, and consequences on the final properties.
Advanced technological processes with the final aim to improve the functional properties of polymers. Curing and post-treatment: polymer annealing and welding.
Principles of reactive extrusion, and the use of maleimide to compatibilize polyolefins. Types of extruders, masterbatches and their insertion in polymer manufacturing.
Polymer solution processing: fiber spinning and coating. Electrospinning.
Polymers for biomedical applications. Polymers for contact lenses, description of the synthetic and manufacturing

methods for rigid and soft contact lenses.
The lamination process for the preparation of multilayer packaging material, illustrating the issues of adhesion between different polymers and with other substrates.
Multilayered polymer tubing, the issue of gas diffusion in polymers, focus on the preparation of polyvinylalcohol.
Polymer recycling, including the compatibilization of mixed polymer waste using developed multi-block compatibilizers. Depolymerization.
Biopolymers from agricultural sources and their transformation. The many modifications of cellulose (nitrocellulose, cellulose acetate, ect.). Polymer films from treated agrowaste.
Elastomers for the automotive industry, the vulcanization process, main topics of polymer network degradation, stability, and recycling. Open issues in recycling, thermoplastic elastomers, physical and reversible crosslinking.
Self-assembly of polymeric chains for drug delivery, cellular scaffolding, and other nanomedical applications, and for the preparation of patterned surfaces for electronics.
Self-healing polymers. Polymer blends (for example, HIPS).

The course includes lessons with the participation of experts in the field of polymer chemistry.

The student is requested to propose a subject of his/her interest in the field to be presented to the class.

Prerequisites

• Good knowledge of macromolecular chemistry, including the main types of polymerization reactions (step-growth, chain-growth).
• Basic knowledge of thermodynamics, including the concepts of phase transitions in polymers, including glass transition and melting.
• Basic knowledge of the mechanical properties of polymers.

Teaching form

• 9 two-hour lectures, in person, delivered didactics.
• 3 two-hour lectures as delivered didactics, in person, with the participation of experts.
• 15 two-hour lessons, delivered didactically in the initial part, which aims to involve students interactively in the subsequent part. All lessons are held in person.
• 3 two-hour lessons, delivered didactically in the initial part, which aims to involve students interactively in the subsequent part. Industry experts will participate. All lessons are held in person.
• Lectures will be given in English, supported by video projection of text, schemes, diagrams, pictures and movies.

Textbook and teaching resource

1. Polymer Chemistry. S. Koltzenburg, M. Maskos, O. Nuyken. Springer (2017).
2. Hybrid Materials: Synthesis, Characterization, and Applications. Editor: G. Kickelbick. Wiley-VCH (2007). ISBN: 978-3-527-31299-3 4.
3. Understanding Polymer Processing. T.A. Osswald. Carl Hanser Verlag GmbH & Company KG (2015).
4. Lecture Notes.

Semester

First year, second semester.

Assessment method

Oral Exam.
Oral interview about the acquired knowledge during the course and presentation of a chosen topic in the field of polymer chemistry and technology.
The structure of commonplace polymers and the basic concepts in polymer science can also be required.

Office hours

By appointment.

Sustainable Development Goals

INDUSTRY, INNOVATION AND INFRASTRUCTURE | RESPONSIBLE CONSUMPTION AND PRODUCTION