PEOPLE'S DEMOCRATIC REPUBLIC OF ALGERIA

MINISTRY OF HIGHER EDUCATION

AND SCIENTIFIC RESEARCH

Compliance and Harmonization Framework

TRAINING PROGRAM OFFER

L.M.D. Academic Master's Degree

2025 – 2026

Field	Program	Specialization
Materials Science	**Chemistry**	**MATERIALS CHEMISTRY**

Semester 3 :

Teaching Unit (TU)	Courses	VHS	Weekly Hours (WH)			Others	Coeff	Credits	Assessment Method	
	Title	15 Weeks	L	TUT	PW				Assessment	Exam
Fundamental Teaching Unit (FTU) Code : FTU 3 Credits : 18 Coefficient : 9	Physical Chemistry of Surfaces and Interfaces	67h30	3h00	1h30		82h30	3	6	33%	67%
	Applications of Supramolecules in the Solid State	45h00	1h30	1h30		55h00	2	4	33%	67%
	Nanomaterials for Sustainable Development	45h00	1h30	1h30		55h00	2	4	33%	67%
	Crystal Growth	45h00	1h30	1h30		55h00	2	4	33%	67%
Methodology Teaching Unit (MTU) Code : MTU 3 Credits : 9 Coefficient : 5	Practical: Materials Modeling	45h00			3h00	55h00	2	4	50%	50%
	Exploration of Free and Open-Source Software in the Field	15h00			1h00	10h00	1	1	50%	50%
	Practical: Materials Processing Methods 2	22h30			1h30	27h30	1	2	50%	50%
	Practical: Materials Characterization Techniques 2	22h30			1h30	27h30	1	2	50%	50%
Discovery Teaching Unit Code : DTU 3 Credits : 2 Coefficient : 2	Electrochemical Sensors and Supercapacitors	45h00	1h30	1h30		05h00	2	2	33%	67 %
Transversal Teaching Unit Code : TTU 3 Credits : 1 Coefficient : 1	Entrepreneurship, Innovation, and Startups	22h30	1h30			2h30	1	1		100%
Semester 3 Total		375h	10h30	7h30	7h00	375h	17	30		

Detailed course syllabus by subject for Semester S3

Semester: 3
UE: Fundamental
Course: Physical Chemistry of Surfaces and Interfaces

Course Objectives

The objective of this course is to enable students to understand the fundamental concepts related to surfaces and interfaces, and to apply this knowledge to industrial and technological issues such as catalysis, nanotechnologies, porous materials, and interfacial phenomena.

Recommended Prerequisites

A solid background in general chemistry is recommended, particularly concepts related to chemical bonding, intermolecular interactions, and thermodynamics. Knowledge of the physicochemical properties of materials is also advised.

Course Content

1. Thermodynamics and Structure of Surfaces (8 weeks)

- Introduction
- Basic concepts: surface and interface – macroscopic, microscopic, and nanoscopic scales
- Importance of surfaces and interfaces in materials science, catalysis, biology, and nanotechnologies
- Surface thermodynamics
- Surface energy and surface tension: mechanisms and measurement methods
- Effects of temperature and composition on surface energy
- Adsorption: Langmuir and BET models – isotherms and applications
- Surface structure
- Reconstruction and relaxation of crystalline surfaces
- Surface defects: dislocations, steps, vacancies
- Introduction to surface characterization techniques

2. Interfaces and Interactions with the External Environment (8 weeks)

Types of interfaces

- Solid–solid interfaces (grain boundaries, heterostructures)
- Solid–liquid interfaces (wetting, contact angle, Young's law)
- Solid–gas interfaces (adsorption/absorption, dry corrosion)
- Interfacial phenomena
- Static and dynamic wetting, hysteresis: chemical heterogeneity of surfaces, hydrophobic, superhydrophobic, and hydrophilic surfaces
- Adhesion and cohesion (van der Waals theories, electrostatic interactions)
- Influence of surface roughness and surface chemistry
- Interactions with the external environment
- Interaction with atoms/ions and molecules
- Interaction with electrons (electron emission, triboelectric effects)
- Interaction with photons (reflection, absorption, photocatalysis)

3 Bonding / Adhesion and Characterization Techniques (9 weeks)

- Fundamental principles of adhesion: adhesion theories (mechanical, electrostatic, diffusion, adsorption)
- Bonding mechanisms: chemical bonds, physical interactions, molecular entanglement

- Adhesion characterization techniques: peel tests, shear tests, tensile tests
- Factors affecting the quality of bonded joints: surface preparation, wettability, material compatibility
- Structural and non-structural adhesives: classification and properties
- Techniques for improving adhesion: specific surface treatments
- Aging of bonded interfaces: degradation mechanisms and durability

4. Adsorption Phenomena and Textural Characterization (8 weeks)

- Fundamental concepts and definitions: porous state; porosity and pore size distribution; specific surface area and its importance; classification of porous materials (microporous, mesoporous, macroporous)
- Adsorption phenomena: physical vs. chemical adsorption; involved forces and interactions
- Factors influencing adsorption (temperature, pressure, nature of the adsorbate and adsorbent)
- Adsorption models
- Langmuir model: assumptions (monolayer adsorption), derivation and linearized form, applications and limitations
- Freundlich model: empirical equation for heterogeneous surfaces, form and application domain
- BET theory (Brunauer–Emmett–Teller): extension of Langmuir model to multilayer adsorption; derivation of the BET equation; determination of specific surface area; limitations
- Textural analysis methods:
    - ❖ Gas adsorption/desorption isotherms (IUPAC classification)
    - ❖ Instrumentation for gas adsorption measurements
    - ❖ Mercury porosimetry
    - ❖ Complementary methods (t-plot, BJH)

5. Porous Materials and Their Applications (9 weeks)

- Microporous materials
- Structure, properties, and applications
- Activated carbons: preparation and characteristics
- Mesoporous materials
- Ordered mesoporous materials based on structure-directing surfactants (MCM-41, SBA-15)
- Xerogels and aerogels: synthesis methods and properties
- Applications of porous materials
- Catalysis
- Adsorption and separation
- Energy storage
- Environmental applications

<u>Références</u> *(Livres et polycopiés, sites internet, etc.) :*

- G.A. Somorjai, Y. Li : *Surface Science : Foundations, Technology, and Application*
- R.F. Willis : *Surface Science : Principles and Applications*
- G.L. Richmond : *Interfacial Science : An Introduction*
- Horiuchi, Shin., Terasaki, Nao., Miyamae, Takayuki : *Interfacial Phenomena in Adhesion and Adhesive Bonding*
- T. Davies, E.K. Rideal : *Interfacial Phenomena*
- G.A. Somorjai : *Interfacial Science: An Introduction*
- J.C. Rivière : *Handbook of Surface and Interface Analysis*

Semestre : S3
UE : UEF2
Matière : Applications des supramolécules à l'état solide

Objectifs de l'enseignement

L'objectif de cet enseignement est d'introduire les concepts fondamentaux de la chimie supramoléculaire appliquée aux matériaux à l'état solide. À la fin du semestre, l'étudiant sera capable de comprendre les mécanismes d'auto-assemblage dans les états solides, d'identifier les forces intermoléculaires impliquées, et d'explorer les propriétés physico-chimiques et applications technologiques des matériaux supramoléculaires cristallins.

Connaissances préalables recommandées

Il est recommandé d'avoir bien maîtrisé les bases de la chimie organique, inorganique et physique au niveau licence.

Contenu de la matière :

1. Introduction à la chimie supramoléculaire à l'état solide (3 semaines)

- Différences entre chimie supramoléculaire en solution et à l'état solide
- Forces intermoléculaires : liaisons hydrogène, interactions π–π, forces de Van der Waals, liaisons métal-ligand
- Concepts clés : auto-assemblage, reconnaissance moléculaire, porosité, ordre à longue distance

2. Matériaux supramoléculaires cristallins (7 semaines)

- Réseaux coordinationnels (MOFs – Metal Organic Frameworks)
- COFs (Covalent Organic Frameworks)
- ZIFs (Zeolitic Imidazolate Frameworks)
- Matériaux fluorescents
- Matériaux magnétiques moléculaires photo-commutables
- Nanoparticules supramoléculaires colorées
- Synthèse, caractérisation et stabilité thermique/chimique

3. Propriétés physico-chimiques des matériaux supramoléculaires (5 semaines)

- Porosité et surface spécifique – analyse BET, isothermes d'adsorption
- Propriétés optiques, électroniques et magnétiques
- Mécanismes d'adsorption et d'intercalation
- Changements de phase induits par stimuli (température, pression, lumière)

4. Applications technologiques (6 semaines)

- Stockage et séparation de gaz (CO_2, H_2, CH_4)
- Catalyse hétérogène supramoléculaire
- Détection chimique et capteurs
- Systèmes de libération contrôlée de médicaments
- Matériaux pour l'électronique (transistors organiques, diodes électroluminescentes)

Références (*Livres et polycopiés, sites internet, etc.) :*

- *J.-M. Lehn : *Supramolecular Chemistry: Concepts and Perspectives* – Wiley-VCH*
- *G. Férey : *Metal Organic Frameworks* – Chemistry*
- *Cours de chimie des matériaux poreux, Collège de France.*
- *Articles scientifiques récents (revues : *Nature Materials*, *Advanced Materials*, *Chemical Society Reviews*).*

Semester : S3

TU : TUF2

Course: Applications of Supramolecules in the Solid State

Course Objectives

The objective of this course is to introduce the fundamental concepts of supramolecular chemistry applied to solid-state materials. By the end of the semester, students will be able to understand self-assembly mechanisms in the solid state, identify the intermolecular forces involved, and explore the physicochemical properties and technological applications of crystalline supramolecular materials.

Recommended Prerequisites

A solid background in organic, inorganic, and physical chemistry at the undergraduate (Bachelor's) level is recommended.

Course Content:

1. Introduction to Supramolecular Chemistry in the Solid State (3 weeks)

- Differences between supramolecular chemistry in solution and in the solid state
- Intermolecular forces: hydrogen bonding, π–π interactions, van der Waals forces, metal–ligand bonds
- Key concepts: self-assembly, molecular recognition, porosity, long-range order

2. Crystalline Supramolecular Materials (7 weeks)

- Coordination networks (MOFs – Metal Organic Frameworks)
- COFs (Covalent Organic Frameworks)
- ZIFs (Zeolitic Imidazolate Frameworks)
- Fluorescent materials
- Photo-switchable molecular magnetic materials
- Colored supramolecular nanoparticles
- Synthesis, characterization, and thermal/chemical stability

3. Physicochemical Properties of Supramolecular Materials (5 weeks)

- Porosity and specific surface area – BET analysis, adsorption isotherms
- Optical, electronic, and magnetic properties
- Adsorption and intercalation mechanisms
- Stimuli-induced phase changes (temperature, pressure, light)

4. Technological Applications (6 weeks)

- Gas storage and separation (CO_2, H_2, CH_4)
- Supramolecular heterogeneous catalysis
- Chemical sensing and sensors
- Controlled drug delivery systems
- Electronic materials (organic transistors, light-emitting diodes)

References (Books, lecture notes, websites, etc.):

- J.-M. Lehn: Supramolecular Chemistry: Concepts and Perspectives – Wiley-VCH
- G. Férey: Metal Organic Frameworks – Chemistry
- Courses on porous materials chemistry, Collège de France
- Recent scientific articles (journals: Nature Materials, Advanced Materials, Chemical Society Reviews)

Semester: S3

TU: Fundamental

Course: Nanomaterials for Sustainable Development

Course Objectives

The objective of this course is to develop expertise in nanomaterials used in the fields of energy, environment, and health. Through this course, students will acquire knowledge on the design, characterization, fabrication, and applications of nanomaterials in various sectors related to sustainable development.

Recommended Prerequisites

A solid background in nanosciences and nanotechnologies, materials chemistry, electrochemistry, and the physicochemical properties of materials is recommended.

Course Content:

1. Introduction – Current Context (2 weeks)

- Energy context
- Current status of nanosciences and nanotechnologies in the energy sector

2. Methods for Fabrication of Nanostructures (6 weeks)

- Synthesis and functionalization of nano-objects
- Chemical synthesis in solution
- Production of individual nanoparticles – functionalization
- Organic nano-objects
- Bottom-up approach
- Chemical or electrochemical solution-based synthesis, with or without templates
- Vapor-phase synthesis – vacuum or controlled-atmosphere reactors
- Top-down approach
- Nanostructuring of thin films (lithography, etching techniques)
- Lithography (high technology, miniaturization of electronic and computing components, etc.)
- Nanoelectronics serving humanity and Moore's law

3. Nanomaterials for Energy and Sustainable Development (10 weeks)

- Introduction: Nanomaterials are rapidly expanding in scientific and technological research due to their many innovative applications, whether physical, chemical, or biological
- Nanomaterials for energy conversion
- Photovoltaic conversion of solar energy – current technologies and developments
- Semiconductor materials – general concepts
- P–N junction
- Photovoltaic solar cell – basic operating principle
- Photovoltaic module
- Different technologies: silicon-based, thin-film, organic
- Contribution of nanotechnologies: toward photovoltaic cells based on inorganic nanomaterials
- Multi-junction or tandem solar cells
- Intermediate band solar **cells**Multi–charge generation solar cells
- Photonic conversion cells

- Hot carrier solar cells
- Nanomaterials for Energy Storage
- Fuel cells
- Different technologies
- Basic thermodynamic principles
- Proton exchange membrane fuel cells (PEMFCs)
- Solid oxide fuel cells (SOFCs)
- Hydrogen
- Hydrogen as an energy carrier
- Hydrogen production – different pathways
- Hydrogen storage – solid-state materials and nanostructured composites
- Technological advances in hydrogen production and storage
- Nanomaterials for the Environment
- Applications for water and air treatment
- Replacement of conventional filters with advanced nanomaterials
- Nanomaterials for Health

References (Books, lecture notes, websites, etc.):

Abdelilah Slaoui, Jean-François Guillemoles: Nanomaterials for Photovoltaic Conversion – L'Actualité Chimique, No. 331, June 2009

Florent Bègue, Éric Pineault: Hydrogen: Energy Transition or New Mirage? – Relations, Summer 2022

Abdelilah Slaoui: Nanostructures for Inorganic Photovoltaic Cells – Techniques de l'Ingénieur, 10/08/2010

Daniel Lincot, Ludovic Escoubas, Jean-François Guillemoles, Jean-Jacques Simon, Abdelilah Slaoui: Nanomaterials for Photovoltaic Conversion of Solar Energy

Semester: 3

Teaching Unit (UE): UEF 1

Course Title: Crystal Growth

Course Objectives

The objective of this course is to enable students to:

- Understand the definition of crystal growth and the different mechanisms involved
- Learn how to control crystal growth in order to obtain a specific crystal habit
- Determine crystal growth rates and identify the associated mechanisms

Recommended Prerequisites

A solid understanding of fundamental concepts in solid-state chemistry, as well as the basics of geometric and structural crystallography, is recommended.

Course Content:

1. Introduction (1 week)

2. Crystallization (6 weeks)

- General concepts of crystallization and recrystallization: supersaturation, supercooling, precipitation, the relationship between precipitation and crystallization, and crystal quality
- Crystallization modes:
- Phase transitions (diffusion-controlled and diffusionless transformations)
- Crystallization from solution
- Phase transition mechanisms: liquid → solid, gas → solid, amorphous solid → crystalline solid
- Crystallization from solution: by cooling, solvent evaporation, salting-out, etc.
- Nucleation (or germination): definition, types of nucleation (homogeneous or primary, heterogeneous or secondary), nucleation rate, nucleation mechanisms, conditions for formation and stability of spherical nuclei
- Crystal growth: definition, critical growth rate, thermodynamic and energetic aspects
- Thermodynamic and energetic considerations: parent phase transition and internal energy of multiphase systems
- Crystal habit and crystal faces
- Dynamic aspects: oriented aggregation, dendritic instabilities

3. Theories of Crystal Growth (5 weeks)

- Structure-based theories:
- Crystal growth as a capillary phenomenon (Curie's law)
- Growth rate of crystal faces as a determining factor of crystal shape
- Spherical crystal method
- Dissolution rate of crystal faces
- Gibbs thermodynamic approach
- Wulff theorem
- Hartman–Perdok theory
- Growth and diffusion
- Growth in relation to crystal structure (Haüy's law of multiple stratification)
- Kinetic theories:
- Kossel–Stranski–Volmer theories

- Growth mechanism according to Volmer
- Gilmer and Bennema theory (surface roughness theory: rough and smooth interfaces)
- Frank theory
- Growth mechanisms and rates:
- Expressions for growth rate
- General description and main stages of the crystal growth mechanism

4. Factors Influencing Crystal Growth (4 weeks)

- Solvent effects, additives, and impurities
- Crystal size, temperature, mass transport (diffusion, convection)
- Surface effects: two-dimensional surface nucleation growth (polynucleation mechanism, nucleation and spreading mechanism), dislocations

5. Main Methods and Techniques of Crystal Growth (8 weeks)

- Growth from the molten state:
- Bridgman–Stockbarger process
- Czochralski method
- Kyropoulos method
- Stepanov method
- Edge-Defined Film-Fed Growth (EDFG)
- Verneuil process
- Floating zone technique
- Arc-melting growth
- Growth from solutions:
- Cooling of the solution
- Solvent evaporation
- Salting-out
- Hydrothermal growth
- Growth by physical transport or sublimation
- Growth by chemical transport:
- Chemical Vapor Transport (CVT)
- Chemical Vapor Deposition (CVD)
- Epitaxy:
- Molecular beam epitaxy
- Liquid-phase epitaxy
- Vapor-phase epitaxy
- Sintering, polymerization, sedimentation
- Simple melting and rapid cooling (glass fabrication)

References (Books, lecture notes, websites, etc.):

Jacques Villain, Alberto Pimpinelli: Physics of Crystal Growth, 1999

Daniel R. Neuville, Laurent Cormier, Daniel Caurant, Lionel Montagne: From Glass to Crystal: Nucleation, Growth and Phase Separation – From Research to Applications

Semester: 3

Teaching Unit (TU): Methodology

Course Title: Materials Modeling – Practical Work (Lab)

Course Objectives

This practical module aims to introduce students to simulation and modeling tools used in materials science. Through a series of laboratory sessions, students will be able to use common software packages such as LAMMPS, Quantum ESPRESSO, OVITO, Materials Studio, XCrySDen, WIEN2k, etc., and apply these tools to predict and analyze the physical, mechanical, and thermal properties of materials.

Recommended Prerequisites

A solid background in materials physics, fundamental concepts of theoretical chemistry, and an introductory knowledge of programming or scientific numerical tools are recommended.

Course Content:

1. **Introduction to Modeling Tools**
   - Handling and basic use of software such as LAMMPS, OVITO, Materials Studio, Quantum ESPRESSO (QE), XCrySDen, WIEN2k, etc.
2. **Lennard–Jones Potential**
   - Study of the interaction between two atoms
3. **Molecular Dynamics Simulation of a Crystal**
   - Calculation of temperature, potential energy, and kinetic energy
4. **Crystal Compression (Young's Modulus Calculation)**
   - Plotting stress–strain curves
5. **Atomic Diffusion Study**
   - Calculation of the diffusion coefficient as a function of temperature
6. **Introduction to Density Functional Theory (DFT)**
   - Structure optimization, total energy calculation, etc.
7. **Band Structure and Density of States (DOS)**
   - Calculation and interpretation
8. **Thermal Simulation of a Material**
   - Calculation of thermal conductivity
9. **Study of a Solid/Liquid Interface**
   - Modeling of a heterogeneous system
10. **Comparative Study Between Simulation and Experimental Data**
    - Model validation using measurable properties (elastic modulus, energy, etc.)

Semester: 3

Teaching Unit Title: Methodology

Course Title: Exploration of Free and Open-Source Software in Materials Chemistry

Course Objectives

- Introduce students to the use of open-source software for materials modeling, visualization, and characterization.
- Apply skills in structural analysis, thermodynamic simulation, and atomic-scale modeling.
- Understand computational and data-processing tools used in diffraction, spectroscopy, and physico-chemical property analysis.

Recommended Prerequisites

- Basic knowledge of crystallography, spectroscopy, and thermodynamics.
- Fundamental background in solid-state materials chemistry.
- Introductory familiarity with Linux environments and scientific software.

Detailed Course Program

Chapter I. Introduction to Open-Source Software in Materials Science

- Advantages of open-source tools
- Overview of commonly used software: VESTA, Avogadro, Thermo-Calc (demo version), LAMMPS, Phonopy, GDIS

Chapter II. Structural Visualization and Modeling

- Use of VESTA and Avogadro for visualization of crystalline and amorphous structures
- Unit cell construction and modeling of crystal defects
- Exporting and converting file formats (CIF / PDB / XYZ)

Chapter III. Structural Analysis and Diffraction

- X-ray diffraction analysis using FullProf and GSAS-II
- Indexing and Rietveld refinement
- Extraction of structural parameters

Chapter IV. Property Simulation and Atomistic Calculations

- Introduction to molecular dynamics simulations using LAMMPS
- Concepts of structural relaxation, supercell construction, and cohesive energy modeling
- Phonon calculations with Phonopy (solid-state thermodynamics)

Chapter V. Spectroscopy and Data Processing

- Processing of FTIR, UV–Vis, and Raman spectroscopic data using Fityk and ORIGIN
- (open-source alternatives: QtiPlot, SciDAVis)

- Peak extraction and deconvolution
- Interpretation of spectroscopic data for materials characterization

Chapter VI. Applied Mini-Project

- Individual or pair-based project: modeling, visualization, or data processing of a selected material
- Illustrated written report and oral presentation

Recommended References

VESTA: https://jp-minerals.org/vesta/en/
Avogadro: https://avogadro.cc/
LAMMPS: https://www.lammps.org/
Phonopy: https://phonopy.github.io/phonopy/
GSAS-II: https://subversion.xray.aps.anl.gov/pyGSAS/
FullProf: https://www.ill.eu/sites/fullprof/
Fityk: https://fityk.nieto.pl/
QtiPlot: https://www.qtiplot.com/

Semester: 3

Teaching Unit: Methodology

Course Title: Practical Work – Materials Synthesis 2

Course Objectives

The objective of this practical module is to provide students with the fundamental knowledge required to better understand the physical and structural properties of nanostructured materials and thin films synthesized by electrodeposition, chemical bath deposition, and hydrothermal methods.
By the end of this course, students will be able to carry out and analyze the synthesis of nanostructures based on II–VI semiconductors and doped metal oxides.

Recommended Prerequisites

It is recommended that students have a solid background in electrochemistry, electrodeposition, thin film fabrication techniques, chemical bath deposition (CBD), as well as basic principles of molecular beam epitaxy.

Course Content

1. **Electrodeposition of thin films based on transition metals** (Ni, Co, Fe)
2. **Chemical bath deposition of II–VI semiconductor nanostructures** (ZnO–ZnS)
3. **Electrodeposition of nanostructures based on zinc oxide (ZnO) and copper oxide (Cu_2O)**
4. **Doping of semiconductor oxides**

ZnO:Al (AZO)
ZnO:Mg (MGO)
Chlorine doping of p-Cu_2O to obtain n-Cu_2O

5. **Synthesis of semiconductor junctions by electrodeposition and chemical bath deposition**

ZnO and Cu_2O
p-Cu_2O / n-ZnO heterojunctions
p-Cu_2O / n-Cu_2O homojunctions

6. **Chemical bath deposition of ZnS thin films**
7. **Doping of ZnO and Cu_2O semiconductors**

ZnO:Al (AZO)
ZnO:Mg (MGO)
Cl-doped p-Cu_2O (n-Cu_2O)

8. **Fabrication of heterojunctions and homojunctions**

p-Cu_2O / n-ZnO heterojunctions
p-Cu_2O / n-Cu_2O homojunctions
using electrodeposition and chemical bath methods

9. **Hydrothermal synthesis of semiconducting metal oxides**

References (Books, lecture notes, and online resources)

Semester: 3

Teaching Unit: Methodology

Course Title: Practical Work – Materials Characterization 2

Course Objectives

This practical module aims to introduce students to advanced materials characterization techniques, particularly for transparent conductive oxides and nanostructured materials.
Through a series of laboratory sessions, students will be able to apply techniques such as Atomic Force Microscopy (AFM), X-ray Diffraction (XRD), UV–VIS–NIR optical measurements, and Mott–Schottky analysis to evaluate the structural, morphological, optical, and electrical properties of materials.

Recommended Prerequisites

It is recommended that students have a solid background in materials physics, crystallography, and an introductory knowledge of physico-chemical characterization methods.

Course Content

1. **Estimation of charge carrier concentration using Mott–Schottky analysis**
   - Principle of the Mott–Schottky technique
   - Measurement of charge carrier density
   - Data analysis applied to transparent conductive oxides

2. **Morphological characterization by Atomic Force Microscopy (AFM)**
   - Operating principles of AFM
   - Sample preparation
   - Surface roughness and topography analysis
   - Visualization of nanometric structures
3. **Optical characterization using UV–VIS–NIR spectroscopy**
   - Measurement of the absorption coefficient and determination of the optical band gap
   - Electrical resistivity measurements
   - Determination of thin film thickness
   - Interpretation of optical spectra

4. **Structural characterization by X-ray Diffraction (XRD)**
   - XRD applied to transparent conductive oxides (ZnO, Cu_2O)
   - Identification of crystalline phases
   - Qualitative and quantitative analysis of diffraction patterns

5. **Structural characterization of nanostructures by X-ray diffraction (XRD)**
6. **Photoactivity characterization of transparent and semiconducting metal oxides**

References (Books, lecture notes, and online resources)

Semester: 3

Teaching Unit: Transversal

Course Title: **Entrepreneurship, Innovation, and Startups**

Course Objectives

The objective of this module is to train students in the fundamentals of project management and to support them in the creation of innovative enterprises. Through a group-based workshop format, students will be able to:

- Master project management methods and tools (Gantt charts, Scrum, Business Model Canvas)
- Design a structured business plan and identify funding sources (venture capital, public funding schemes)
- Develop a practical project (prototype or startup) as a team, including an oral presentation and a persuasive pitch
- Adopt an entrepreneurial approach that integrates project management and innovation challenges

Recommended Prerequisites

A general background in project management is recommended, along with sufficient scientific and technical knowledge to understand the links between technological innovation and entrepreneurship.

Course Content

1. **Fundamentals of Entrepreneurship (4 weeks)**

- Definition of entrepreneurship: value creation through innovation and risk-taking
- Pillars of entrepreneurship: opportunity, innovation, risk management, value creation
- The entrepreneurial ecosystem: scientist-entrepreneurs, investors, incubators, clusters
- Business creation process: ideation → validation → business plan → launch → growth
- Scientific and technical challenges: patents, standards, R&D funding, multidisciplinary teamwork
- Practical cases: patent filing simulation, funding search

2. **Entrepreneurial Mindset in Science and Technology (3 weeks)**

- Understanding scientific and technological entrepreneurship
- Entrepreneurial mindset: creativity, innovation, resilience, risk management
- Motivations for entrepreneurship in scientific and technological fields
- Major opportunity sectors: energy, health, materials, digital technologies, environment, food sciences

3. **From Scientific Research to Entrepreneurial Opportunity (4 weeks)**

- Transforming scientific or technological discoveries into entrepreneurial projects
- “Problem–solution” approach: identification of real-world needs
- Introduction to market studies applied to scientific projects
- Rapid idea validation: minimum viable product (MVP), surveys, user testing

4. **Building and Modeling an Innovative Project (3 weeks)**

- Introduction to the Business Model Canvas (BMC) for technological projects
- Defining a clear and differentiated value proposition
- Identifying key resources, strategic partners, and distribution channels
- Launching a Scientific or Technological Project (4 weeks)
- Key steps to move from an idea to a structured project
- Typical early-stage funding sources: seed funds, competitions, private support
- Pitching skills: communicating innovation effectively to investors, partners, and early customers
- Common pitfalls to avoid: poor market assessment, technology development disconnected from real needs

5. **Succeeding and Growing as a Scientific Entrepreneur (4 weeks)**

- Risk and uncertainty management in innovative projects
- Pivot strategies: adapting projects based on market feedback
- Scientific leadership: organizing and leading multidisciplinary teams
- Intellectual property fundamentals: patents, licensing, innovation valorization
- Impact entrepreneurship: addressing environmental, social, and economic challenges
- Continuous development: innovation networks, incubators, mentors, lifelong learning

References

Verstraete, T., Fayolle, A.: Entrepreneurship – Foundations and Dynamics – De Boeck Supérieur, 2005

Julien, P.-A.: Entrepreneurship – Becoming an Entrepreneur: Theories and Practices – Economica, 2007

Schieb-Bienfait, N., Lemoine, V.: Entrepreneurship – Entrepreneurial Theories and Realities – EMS, 2013

Fayolle, A.: Entrepreneurship – Learning to Become an Entrepreneur – Dunod, 2014

Project Management Institute (PMI): A Guide to the Project Management Body of Knowledge (PMBOK® Guide) – 7th Edition, 2021

Ezratty, O.: Startup Guide – Free annual edition

Blank, S.: The Startup Owner’s Manual: The Step-by-Step Guide for Building a Great Company – K&S Ranch, 2012

Semester: 3

Teaching Unit: Transversal

Course Title: Entrepreneurship, Innovation, and Startups

Course Objectives

The objective of this module is to train students in the fundamentals of project management and to support them in the creation of innovative enterprises. Through a group-based workshop format, students will be able to:

- Master project management methods and tools (Gantt charts, Scrum, Business Model Canvas)
- Design a structured business plan and identify funding sources (venture capital, public funding schemes)
- Develop a practical project (prototype or startup) as a team, including an oral presentation and a persuasive pitch
- Adopt an entrepreneurial approach that integrates project management and innovation challenges

Recommended Prerequisites

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Course Content

1. **Fundamentals of Entrepreneurship (4 weeks)**

- Definition of entrepreneurship: value creation through innovation and risk-taking
- Pillars of entrepreneurship: opportunity, innovation, risk management, value creation
- The entrepreneurial ecosystem: scientist-entrepreneurs, investors, incubators, clusters
- Business creation process: ideation → validation → business plan → launch → growth
- Scientific and technical challenges: patents, standards, R&D funding, multidisciplinary teamwork
- Practical cases: patent filing simulation, funding search

2. **Entrepreneurial Mindset in Science and Technology (3 weeks)**

- Understanding scientific and technological entrepreneurship
- Entrepreneurial mindset: creativity, innovation, resilience, risk management
- Motivations for entrepreneurship in scientific and technological fields
- Major opportunity sectors: energy, health, materials, digital technologies, environment, food sciences

3. **From Scientific Research to Entrepreneurial Opportunity (4 weeks)**

- Transforming scientific or technological discoveries into entrepreneurial projects
- "Problem–solution" approach: identification of real-world needs
- Introduction to market studies applied to scientific projects
- Rapid idea validation: minimum viable product (MVP), surveys, user testing

4. **Building and Modeling an Innovative Project (3 weeks)**
- Introduction to the Business Model Canvas (BMC) for technological projects
- Defining a clear and differentiated value proposition
- Identifying key resources, strategic partners, and distribution channels

5. **Launching a Scientific or Technological Project (4 weeks)**
- Key steps to move from an idea to a structured project
- Typical early-stage funding sources: seed funds, competitions, private support
- Pitching skills: communicating innovation effectively to investors, partners, and early customers
- Common pitfalls to avoid: poor market assessment, technology development disconnected from real needs

6. **Succeeding and Growing as a Scientific Entrepreneur (4 weeks)**
- Risk and uncertainty management in innovative projects
- Pivot strategies: adapting projects based on market feedback
- Scientific leadership: organizing and leading multidisciplinary teams
- Intellectual property fundamentals: patents, licensing, innovation valorization
- Impact entrepreneurship: addressing environmental, social, and economic challenges
- Continuous development: innovation networks, incubators, mentors, lifelong learning

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