

2026-2027

**Master 2**  
**Second year of the Master SGM-PSL**  
**Track MADI**



*Ver. 2026/02/18*

# MASTER MATERIALS SCIENCE AND ENGINEERING

## TRACK M2 Materials for the future: Design and Engineering: MADI

### Master 2: Track « Materials for the future: Design and Engineering » - MADI

**The track “Materials for the future: Design and Engineering” provides an “integrated” perspective of various materials of the future, including synthesis processes, desired structure or architecture, eco-design and lifespan. It delivers strategies to properly design a material from a technical point of view and to answer precise economics and environmental requirements specifications. In such multidisciplinary approach, team work on joint projects (design project, tutored project), gathering students with various backgrounds, is essential.**

The MADI track is structured around a specialization elective, to be chosen from among three options, focusing either Materials for Energy, Materials for a Sustainable Lifestyle, and Materials for Transport and Structures. The MADI track emphasizes either an engineering or a design approach, focusing on one or several families of materials and/or on their environmental impact. Additionally, two courses in communication and scientific openness complete the curriculum. This track can also be pursued under a professional training contract.

# MASTER MATERIALS SCIENCE AND ENGINEERING

## TRACK M2 Materials for the future: Design and Engineering: MADI

### **Elective « Sustainable Energy and Materials » - E1**

The elective “Sustainable Energy and Materials” focuses on the phenomena occurring within conversion devices (batteries, fuel cells, photovoltaic systems, etc.). Students will learn how (i) to identify the typical responses of a device based on the underlying chemistry and specific materials involved, (ii) to calculate the energies and power outputs from conventional electrochemical test results, and (iii) to adapt a device according to the specifications of the targeted application. Key issues, challenges, modelling approaches, and recycling strategies will be also addressed.

### **Elective « Materials for Sustainable Lifestyle » - E2**

The elective “Materials for Sustainable Lifestyle” focuses on the elaboration of materials in the framework of sustainable development. It covers a field of techniques starting from the most ancient ones (materials of the cultural heritage) to the most recent ones (materials for housing, for recycling systems). It aims to analyse the constraints associated with resources and environment, social acceptance in order to deliver to the students the technical and scientific knowledge necessary to the fabrication of materials for our everyday life. It analyses the behaviour of materials all along their lifetime (eco-design, durability, recycling).

### **Elective « Engineering Resilient Materials for Transport and Structures » - E3**

The elective “Engineering Resilient Materials for Transport and Structures” focuses on understanding and improving the physico-chemical and mechanical properties of various classes of materials used in infrastructure and transport systems. It addresses the design, performance, durability, and resilience of structural materials, while integrating key considerations of safety, sustainability, and environmental impact.

Students will develop both scientific and applied skills to tackle the challenges of future cities and mobility systems. The course adopts a synergetic approach to explore the fundamental physical and chemical behavior of major material families — metals, ceramics, inorganic materials, and polymers.

By the end of this elective, students will be able to conceptualize and design innovative materials tailored to specific applications, in alignment with defined scientific, technical, economic, and environmental specifications, and in dialogue with complementary disciplines such as marketing and industrial design.

# MASTER MATERIALS SCIENCE AND ENGINEERING

## TRACK M2 Materials for the future: Design and Engineering: MADI

Semester 3		ECTS	E1	E2	E3
<b>5 mandatory units (14 ECTS) + 4 optional units (16 ECTS)</b>					
<b>MATERIAL SCIENCE SPECIALIZATION (ELECTIVE)</b>		<b>117 h</b>	<b>20</b>		
<i>Selection and design of materials for a sustainable city (MAD-CHO)</i>		39h		M	M
<i>Sustainable Energy and Materials (MAD-ENE)</i>		60 h		M	
<i>Life cycle assessment (LCA)</i>		39 h		M	M
<i>Recycling (MAD-REC)</i>		39 h		M	
<i>Materials for everyday life: scientific challenges (MAD-QUOT)</i>		39 h			M
<i>Endurance and durability of metallic materials (MAD-AGE)</i>		42 h			M
<i>Physical metallurgy (MAD-PHYS)</i>		42 h			M
<i>Processes and coatings (MAD-COAT)</i>		39 h			M
<i>Materials of the cultural heritage and durability (MAD-PAT)</i>		39 h			M
<b>INNOVATION APPLICATION CLASSES: Group 1 OR Group 2</b>			<b>6</b>		
<b>Group 1</b>			<b>6</b>	O	O
<i>Managing the unknown</i>		30	<b>3</b>	M	M
<i>Tutored project</i>		27	<b>3</b>	M	M
<b>Group 2</b>			<b>6</b>	O	O
<i>Design Thinking</i>			<b>3</b>	M	M
<i>Design Project</i>			<b>3</b>	M	M
<b>COMMUNICATION AND SCIENTIFIC OPENNESS</b>		<b>57 h</b>	<b>4</b>		
<i>Language (NC)</i>		20 h	2	M	M
<i>History of science and technology in society (NC) (mandatory for Group 1 students)</i>		20h	2	M	M
<i>PSL week (NC) (mandatory for Group 2 students)</i>		30h	2	M	M
<b>Total S3</b>		<b>294</b>	<b>30</b>		
<b>Semester 4</b>		<b>mandatory internship (5 to 6 months), 30 ECTS *</b>	<b>30</b>		
<b>Total S4</b>			30		
<b>Total M2</b>		294	60		

M: mandatory course for the given elective

O: optional innovation application classes: either group 1 OR Group 2



Courses are taught in English.

# MASTER MATERIALS SCIENCE AND ENGINEERING

## TRACK M2 Materials for the future: Design and Engineering: MADI

In case of professionalization contract:

Semester 3 Pro 5 mandatory units (14 ECTS) + 4 optional units (16 ECTS)		ECTS	E1	E2	E3
<b>MATERIAL SCIENCE SPECIALIZATION (ELECTIVE)</b>	<b>117 h</b>	<b>20</b>			
<i>Selection and design of materials for a sustainable city (MAD-CHO)</i>	39h		M	M	M
<i>Sustainable Energy and Materials (MAD-ENE)</i>	60 h		M		
<i>Life cycle assessment (MAD-LCA)</i>	39 h		M	M	
<i>Recycling (MAD-REC)</i>	39 h		M		M
<i>Materials for everyday life: scientific challenges (MAD-QUOT)</i>	39 h			M	
<i>Endurance and durability of metallic materials (MAD-AGE)</i>	42 h				M
<i>Physical metallurgy (MAD-PHYS)</i>	42 h				M
<i>Processes and coatings (MAD-COAT)</i>	39 h			M	M
<i>Materials of the cultural heritage and durability (MAD-PAT)</i>	39 h			M	
<b>INNOVATION APPLICATION CLASSES: Group 1bis</b>		<b>6</b>			
<b>Group 1bis</b>		<b>6</b>	M	M	M
<i>Managing the unknown</i>	30	<b>3</b>	M	M	M
<i>Tutored project</i>	27	<b>3</b>	M	M	M
<b>COMMUNICATION AND SCIENTIFIC OPENNESS</b>	<b>57 h</b>	<b>4</b>			
<i>Language (NC)</i>	20 h	2	M	M	M
<i>Report on the first period in the company (NC)</i>	20h	2	M	M	M
<i>PSL week (NC) (mandatory for Group 2 students)</i>	30h	2	M	M	M
<b>Total S3 Pro</b>	<b>294</b>	<b>30</b>			
<b>Semester 4 Pro - mandatory internship (5 to 6 months), + UE</b>		<b>30</b>			
<i>Mandatory internship (from the end of the semester to the end of the professionalization contract)</i>		28			
<i>History of sciences and technologies in the society</i>	20h	2			
<b>Total S4 Pro</b>		<b>30</b>			
<b>Total M2</b>	<b>294</b>	<b>60</b>			

# MASTER MATERIALS SCIENCE AND ENGINEERING

## TRACK M2 Materials for the future: Design and Engineering: MADI

The program starts beginning of September.

Typical week schedule :

	Monday	Tuesday	Wednesday	Thursday	Friday
Morning	*	MAD-QUOT MAD-PHYS	MAD-ENE	<b>MAD-CHO</b>	
Afternoon	MAD-THINK MAD-HIST	MAD-COAT	MAD-ENE	MAD-LCA MAD-AGE	MAD-PAT MAD-REC

Managing the unknown (MAD-INNO) is scheduled during a full week in November.

The project associated with MAD-DES and MAD-THINK takes place during the last week of January.

The cultural openness week is scheduled the last week of November via the PSL weeks.

Language courses are scheduled one evening per week between 18h15 and 20h15.

# MASTER MATERIALS SCIENCE AND ENGINEERING

## TRACK M2 Materials for the future: Design and Engineering: MADI

<b>MAD-CHO</b>	<b>SELECTION AND DESIGN OF MATERIALS FOR A SUSTAINABLE CITY</b> <i>Tags:</i> composition-microstructure-property relationships, material design, material selection, performance				
Responsible	frederic.prima@chimieparistech.psl.eu				
Teachers	Daniel Caurant, Jean-Baptiste d'Espinose, Alba Marcellan, Fan Sun, Lola Lilensten, Frédéric Prima, Philippe Vermaut				
<i>ECTS</i> 4	<i>Course</i> 39 h	<i>Tutorials</i>	<i>Exam</i>	<i>Written</i> 100%	
<i>Course outline:</i>  This course provides a method for selecting the most efficient material for a given application defined by specifications. Ashby's method of material selection strategy is presented in a theoretical way. The composition-microstructure-property relationships are studied in general terms and through examples relating to housing and urban materials: cements, ceramics, glass and glass ceramics, metal alloys, polymers. Composite materials and architectural materials (whose characteristic dimension is in the order of mm) are approached as materials capable of associating properties that are a priori incompatible, and with the idea of encouraging the student to imagine new possibilities in a functional design approach. The examples also illustrate the environmental functions of materials: lightening, thermal insulation in particular.					
<i>Learning outcomes:</i>  At the end of this course the student must: <ul style="list-style-type: none"><li>□ Know the definition and concrete examples of composite or architectural materials</li><li>□ Know how to design new materials, especially for sustainable cities Use the Ashby method of material selection</li><li>□ Know how to compare the mechanical and thermal properties of the major classes of materials.</li></ul>					

# MASTER MATERIALS SCIENCE AND ENGINEERING

## TRACK M2 Materials for the future: Design and Engineering: MADI

<b>SUSTAINABLE ENERGY AND MATERIALS</b>					
<b>MAD.ENE</b>	<i>Tags: photovoltaics, fuel cells, hydrogen, batteries, thermoelectricity, piezoelectricity...</i>				
Responsible	Armelle Ringuedé armelle.ringuede@chimieparistech.psl.eu				
Teachers					
<i>ECTS</i> 8	<i>Course</i> 90 h	<i>Tutorials</i>	<i>Exam</i> Written 100%		
<i>Course outline:</i>  The increase of the global demand in energy needs to find alternatives to fossil resources. The request for sources of natural but sporadic energies (solar with photovoltaics, wind, hydrodynamics...) is increasing. It is thus necessary to couple these sources with systems allowing the recycling and storage of these energies (batteries, supercapacitors). The strong environmental constraint leads to the development of clean systems of storage such as fuel cells. However, it is time to stop this race towards more and more energy and to limit our consumption. In this module, we'll see which materials can be used to store and recycle energy for the various as-mentioned systems. For each of them, the mature technologies, new approaches and environmental challenges will be addressed.					
<i>Learning outcomes:</i>  Students will be able to: <ul style="list-style-type: none"><li>□ understand the phenomena occurring inside batteries</li><li>□ recognize typical responses of a storage device as a function of the involved chemistry</li><li>□ calculate the provided energy and power from results of classical electrochemical tests</li><li>□ adapt a storage device as a function of the requirements of the application</li></ul>					

# MASTER MATERIALS SCIENCE AND ENGINEERING

## TRACK M2 Materials for the future: Design and Engineering: MADI

<b>MAD-LCA LIFE CYCLE ASSESSMENT</b>							
<i>Tags: circular economy, life cycle analysis</i>							
Responsible Daye Lee daye.lee@espci.fr							
Teachers							
ECTS 4	Course 9 h	Tutorials 30 h	Exam	Written 50%	C.A.	Oral 50%	
<p><i>Course outline:</i></p> <p>This course introduces the principles, frameworks, and practical methodologies of Life Cycle Assessment – a fundamental approach for quantifying and understanding the environmental impacts of products, materials, and processes across their entire life cycle, from raw material extraction to end-of-life treatment.</p> <p>Students learn how to structure an LCA study, define system boundaries, select appropriate impact assessment methods, and critically interpret results. By engaging with several case studies and hands-on LCA tools, students develop the ability to identify environmental hotspots, evaluate trade-offs, and propose science-based strategies for process optimization.</p> <p>The course places particular emphasis on how LCA supports eco-innovation, sustainable materials design, and responsible decision-making within engineering contexts. By the end of the course, students will be equipped to apply LCA as a decision-support tool to improve environmental performance and contribute to sustainability challenges in materials and process engineering.</p>							
<p><i>Learning outcomes:</i></p> <ul style="list-style-type: none"> <li>□ Understand the principles, scope, and methodology of Life Cycle Assessment (LCA) as defined by international standards (ISO 14040/44);</li> <li>□ Identify and describe the stages of a product’s life cycle and their associated environmental impacts;</li> <li>□ Use LCA tools and software to model products and processes, and to interpret quantitative results;</li> <li>□ Critically assess the environmental performance of materials, products, or technologies based on LCA results;</li> <li>□ Propose strategies to reduce environmental impacts and improve sustainability in materials selection and process design;</li> </ul> <p><i>Prerequisites:</i></p> <ul style="list-style-type: none"> <li>□ Notions in all fields of chemistry at the level of a M1 in chemistry</li> <li>□ A good understanding of materials science and industrial processes;</li> <li>□ Familiarity with environmental or sustainability concepts;</li> <li>□ Basic skills in data analysis and the use of Excel or similar tools;</li> </ul>							

# MASTER MATERIALS SCIENCE AND ENGINEERING

## TRACK M2 Materials for the future: Design and Engineering: MADI

<b>MAD-REC OVERVIEW OF RECYCLING PORCESSES</b>							
<i>Tags: circular economy, recycling</i>							
Responsible	Frédéric Rousseau frederic.rousseau@chimieparistech.psl.eu						
Teachers	Grégory Lefèvre, Domitille Giaume, Vincent Semetey, Virginie Lair, Julien Comel, Valerie Massardier, Michael Bozlar						
<i>ECTS</i>	<i>Course</i>	<i>Tutorials</i>	<i>Exam</i>	<i>Written</i>	<i>C.A.</i>	<i>Oral</i>	
4	39 h	12 h		50% ??		100%	
<p><i>Course outline:</i></p> <p>This course offers a comprehensive exploration of the principles, processes, and challenges involved in recycling engineering materials. It spans the entire recycling chain—from collection and sorting to material recovery, refining, and reuse—while addressing both technological and environmental dimensions. Through case studies on batteries, solar panels, metallic alloys, polymers, and packaging materials, students will examine the increasing complexity and diversity of modern waste streams. The course provides an in-depth comparison of mechanical, pyrometallurgical, and hydrometallurgical recycling methods, evaluating their efficiency, environmental impact, and economic viability. Key topics include material contamination, property degradation, energy demands, and the critical role of eco-design in enhancing recyclability and promoting circularity. The oral evaluation is based on an inverted pedagogy approach: developing the 'Introduction, General Principles, and Examples' section of a Materials Recycling course</p>							
<p><i>Learning outcomes:</i></p> <ul style="list-style-type: none"> <li>□ Understand the main principles and driving forces of materials recycling and their role in the circular economy;</li> <li>□ Identify and describe the key stages of recycling processes - collection, sorting, separation, recovery, and reuse;</li> <li>□ Compare different recycling routes (mechanical, pyrometallurgical, hydrometallurgical) and assess their advantages, limitations, and environmental impacts;</li> <li>□ Analyze specific case studies such as batteries, photovoltaic modules, metallic alloys, and packaging materials;</li> <li>□ Evaluate the quality, efficiency, and sustainability of recycling strategies;</li> <li>□ Propose innovative and realistic approaches to improve material recovery and reduce resource losses.</li> </ul>							
<p><i>Prerequisites:</i></p> <ul style="list-style-type: none"> <li>□ A solid foundation in materials science (structure, properties, and processing);</li> <li>□ Basic knowledge of chemistry, thermodynamics, and phase equilibria;</li> <li>□ An understanding of industrial processes for materials production and transformation;</li> <li>□ Interest in environmental issues, sustainability, and circular economy concepts;</li> </ul>							

# MASTER MATERIALS SCIENCE AND ENGINEERING

## TRACK M2 Materials for the future: Design and Engineering: MADI

<b>MAD-QUOT</b>		<b>MATERIALS FOR EVERYDAY LIFE: SCIENTIFIC CHALLENGES</b>		
Responsible		Corinne Soulié-Ziakovic, professeure, ESPCI corinne.soulie@espci.psl.eu		
Teachers				
<i>ECTS</i>	<i>Course</i>	<i>Tutorials</i>	<i>Exam</i>	<i>Written (reports)</i>
4	36 h			100%
<i>Course outline :</i>				
<p>This course aims to address present and future challenges in the field of material design through everyday life materials in various applications. Through some selected materials, this course shows the link between requirements of physical and chemical properties imposed by a given application or societal context and its translation in terms of scientific issues to solve to fulfil them. Fabrication processes are also addressed.</p> <p>The course relies on examples of advanced formulations required to elaborate materials that respect multiple constraints that can be opposite (comfort, legislation, environment) to show materials evolution with time.</p> <p>Examples of materials selected to illustrate the course :</p> <ul style="list-style-type: none"> <li>□ Building materials (cement)</li> <li>□ Glass and its optical properties</li> <li>□ Packaging : mechanical properties of polymers</li> </ul>				
<i>Learning outcomes:</i>				
<ul style="list-style-type: none"> <li>□ Link physical properties to chemical structures and constraints on elaboration processes-</li> <li>□ Choose science levers that lead to evolutions of materials properties (chemistry, shaping)</li> <li>□ Propose scientific approaches that help to design materials with improved or combined properties, or even new properties.</li> </ul>				

# MASTER MATERIALS SCIENCE AND ENGINEERING

## TRACK M2 Materials for the future: Design and Engineering: MADI

<b>MAD-COAT</b>		<b>PROCESSES AND COATINGS</b>			
		<i>Tags: coatings, thin films, surface treatments</i>			
Responsible		Frédéric Rousseau, Chimie ParisTech frederic.rousseau@chimieparistech.psl.eu			
Teachers					
<i>ECTS</i> 4	<i>Course</i> 33 h	<i>Practicals</i> 3h + 3h of project	<i>Exam</i> <i>Poster : 50%</i>	<i>Oral</i> 50%	
<i>Course outline:</i>					
<p>Examples of surface treatments as well as organic and inorganic coatings are introduced to the students. These examples come from literature data, industrial processes or research activities led by the research teams of the three engineering schools.</p> <p>Properties and techniques of surface treatments either by wet (sol gel, electrochemistry, colloidal dispersion) or dry (physical or chemical techniques of coating by vapour or plasma deposition) processes. The course includes quick demonstrations and illustrated case studies (e.g. electrodes for solar cells). Additional practical work in the lab is proposed: reactor driving, surface treatments or coatings / thin films, physic-chemical characterizations of the as-treated materials...). In addition, a training to a simulation software (COMSOL) used to model coating processes can be proposed.</p>					
<i>Learning outcomes:</i>					
<p>The students will:</p> <ul style="list-style-type: none"> <li>□ understand the importance of surface treatments to provide new properties to a material (resistance to corrosion, insulation, electrical conductivity, wetting, catalytic properties...)</li> <li>□ know the physical and chemical phenomena involved during deposition for various wet and dry processes</li> <li>□ be able to choose a type of coating (thin, thick) depending on the application</li> <li>□ be able to propose relevant techniques to diagnose to study and characterize the coupling process / surface treatments</li> <li>□ be able to select techniques of analysis of the material that allow to validate the surface modification or the coating that was produced.</li> </ul>					

# MASTER MATERIALS SCIENCE AND ENGINEERING

## TRACK M2 Materials for the future: Design and Engineering: MADI

<b>MAD-AGE</b> <b>ENDURANCE AND DURABILITY OF METAL MATERIALS</b> <i>Tags: durability, damage, oxidation</i>					
Responsibles      Cécilie DUHAMEL / Anne-Françoise GOURGUES-LORENZON cecilie.duhamel@minesparis.psl.eu; anne-francoise.gourgues@minesparis.psl.eu					
Teachers					
<i>ECTS</i>	<i>Course</i>	<i>Tutorials</i>	<i>CC (25%)</i>	<i>Final exam :</i> <i>Written</i>	
4	18 h	18 h		75%	
<p><i>Course outline:</i></p> <p>This course deals with mechanical and/or chemical phenomena that lead to the damage and failure of metal materials.</p> <p>The first part of the course focuses on the interaction of metals and metal alloys with a corrosive environment at high temperature. First, the basic concepts of high temperature corrosion are introduced: thermodynamics, oxidation kinetics, oxidation mechanisms. These concepts are then used to describe and explain various forms of oxidation observed in metal alloys. Damage modes associated with the formation of an oxide layer at the surface of a material are then treated. Finally, solutions of prevention and protection against high temperature corrosion will be introduced. The course mainly focuses on high temperature oxidation, i.e., corrosion by reaction with gaseous oxygen. However, other forms of corrosion will be addressed during tutorials and case studies.</p> <p>The second part of the course focuses on the mechanisms of failure due to mechanical loading, and on failure analysis methods. The course starts by an initiation to the failure analysis process (approach, tools and case studies) and reminders on simple mechanical tools (both experimental and numerical) available for the metallurgist. During lectures and tutorials based on real case studies, various modes of damage and fracture will be addressed: ductile fracture (deformable materials), brittle fracture (intra- and intergranular), time-dependent fracture due to cyclic (fatigue) or long-time (creep) loading. Each of these situations will be treated by considering both the physical mechanisms and quantitative design criteria.</p>					
<p><i>Learning outcomes:</i></p> <p>The students will be able to identify failure modes of metal materials and to propose a process to follow to solve the problem.</p> <p>They will be able to appreciate quickly the risks of failure that may be encountered by a given class of materials in given conditions of application and to conduct the preliminary studies necessary to select appropriate materials for a given application.</p>					

# MASTER MATERIALS SCIENCE AND ENGINEERING

## TRACK M2 Materials for the future: Design and Engineering: MADI

<b>MAD-PHYS</b>		<b>PHYSICAL METALLURGY</b>			
		<i>Tags: diffusion, phase transformation, plasticity, dislocations</i>			
Responsible		Mathias LAMARI, Abdelali OUDRISS mathias.lamari@minesparis.psl.eu			
<i>ECTS</i> 4	<i>Cours</i> 18 h	<i>Tutorials</i> 18 h	<i>CC (25%)</i>	<i>Final exam : Written</i> 75%	
<i>Course outline:</i>					
<p>This advanced course of physical metallurgy deals (i) with phase transformations and microstructure evolution in metal alloys, (ii) the mechanisms of plastic deformation and hardening.</p> <p>The first part focuses on the basic concepts of physical metallurgy such as diffusion and thermodynamics of phase equilibrium that allow the description of phase transformations during solidification and precipitation. Nucleation, growth and coarsening of precipitates as well as displacive transformations are addressed from various aspects: thermodynamics, kinetics, physical mechanisms. The specificity of solidification microstructure (dendritic microstructure) is discussed as well. The mechanism of recovery and recrystallization will complete the notions required to understand the evolution of microstructures.</p> <p>In a second part, the concepts of the theory of dislocations in crystals will be developed to allow the description of the physical aspects of plastic deformation in crystalline materials. Thus, the physical principles of lattice friction, interactions between dislocations or with a foreign atom, or with the interface with a precipitate or another grain are used to interpret the yield strength first for a single crystal of a pure metal, then for a polycrystalline and multiphase material. The various hardening mechanisms can then be correlated to the composition and the microstructural characteristics of the metal alloys such as precipitate distribution (volume fraction, size, distance between precipitates) or grain size. The optimization of a metal alloy in terms of yield stress is then obtained by monitoring the parameters of the thermal treatment of the alloy.</p>					
<i>Learning outcomes:</i>					
Handle the advanced concepts of physical metallurgy that are at the origin of the microstructure formation and of the plastic deformation of metal alloys					

# MASTER MATERIALS SCIENCE AND ENGINEERING

## TRACK M2 Materials for the future: Design and Engineering: MADI

<b>MATERIALS OF THE CULTURAL HERITAGE AND DURABILITY</b>							
<b>MAD-PAT</b>	<i>Tags: alteration, complex materials, conservation, cultural heritage, elaboration, multi-scale analytical methods</i>						
Responsible	Odile.majerus@chimie-paristech.fr						
Teachers	O. Majérus						
<i>ECTS</i> 4	<i>Course</i> 27h	<i>Practicals</i> 3h	<i>Tutorials</i> 3h	<i>Exam</i>	<i>Written</i> 50%	<i>Oral</i> 50%	
	<p><i>Course outline</i></p> <p>The dominance of materials contributes to drive human civilizations. The materials of Cultural heritage have been first produced by humans in a given historical context, then they have evolved in their conservation environment. These materials keep the memory of their origin and of their evolution, which is printed in their multi-scale structure (nano to macro). They are witnesses of our history and should be conserved for the future generations. Studying these materials also helps in anticipating the evolution of current modern materials. This course is multi-materials and multi-disciplinary, encompassing the domains of materials sciences, analytical physical chemistry, human and social sciences. It enriches the general knowledge of students about materials and gives to them tools and examples to predict and evaluate the durability of materials in a given environment. It consists in interactive lectures relying on the basic knowledge of students on materials, in a 3 hours tutorial and in a series of research conferences.</p>						
	<p><i>Learning outcomes:</i></p> <p>At the end of the course, students:</p> <ul style="list-style-type: none"> <li>□ Have a consolidated knowledge of the specificities of different classes of materials (composition domain, chemical bond, structure, microstructure, elaboration process),</li> <li>□ Have developed their culture of materials, thanks to the historical point of view,</li> <li>□ Are able to propose an analytical approach adapted to a specific material,</li> <li>□ Are able to anticipate the probable evolution of a material in a given environment.</li> </ul> <p>These abilities are evaluated by a final written examination containing general questions on materials and the resolution of a case study from the literature. In addition, students conduct an interview with a specialist of Cultural Heritage, and they have to report on the experimental approach and results of a study of this specialist.</p>						

# MASTER MATERIALS SCIENCE AND ENGINEERING

## TRACK M2 Materials for the future: Design and Engineering: MADI

<b>MAD-THINK + MAD-DES</b>		<b>DESIGN THINKING</b>					
		<i>Tags: design, innovation</i>					
Responsible		faustine.vanhulle@gmail.com					
Teachers		Khaoula Bya, Faustine Vanhulle					
<i>ECTS</i>	<i>Course</i>	<i>Tutorials</i>	<i>Exam</i>	<i>Written</i>	<i>C.A.</i>	<i>Oral</i>	
3	14h	10.5h + 16h of project work		50%		50%	
<i>Course outline:</i>							
<p>During this course, we will introduce and apply the “Design Thinking” approach to a real issue proposed by a company (e.g. LVMH, Vicat ...).</p> <p>Design Thinking is a human-centred, iterative approach to problem solving that emphasizes empathy, creativity and experimentation. It focuses on understanding the needs of users, challenging assumptions and redefining problems to identify alternative strategies and solutions. The process encourages collaboration across diverse teams and promotes the exploration of many ideas aiming for innovative, user centred outcomes.</p> <p>Hence, in the frame of the course, students will start from the initial formulation of the issue (challenge), observe and interact with stakeholders and users or customers to understand and gain insights on their needs and define the problem. They will then find options to propose an innovative solution (MAD-THINK). Intermediary sessions will be devoted to an iteration of the process, refinement of the positioning, definition of the technical feasibility and of the business model and control of the sustainability of the proposed solution.</p> <p>The solution(s) selected for their innovative potential will be developed during the Design Project (MAD-DES), that will give the groups the opportunity to prototype and test their ideas, before presenting them.</p> <p>This course is built on both lectures and practical workshop conducted by coaches in innovation, designers and scientists.</p>							
<i>Learning outcomes:</i>							
<ul style="list-style-type: none"> <li>❑ Identify innovation in a given field (difference between innovation and invention)</li> <li>❑ Use the tools of Design thinking to generate innovative ideas, prototype and test them, and confront them to the market</li> <li>❑ Evaluate technical feasibility, and business viability</li> </ul>							

# MASTER MATERIALS SCIENCE AND ENGINEERING

## TRACK M2 Materials for the future: Design and Engineering: MADI

<b>MAD.HIST</b> <b>History of Science and Technology in Society</b> <i>Tags:</i>						
Teachers		Emanuel Bertrand				
Responsible		emanuel.bertrand@espci.psl.eu				
<i>ECTS</i>	<i>Course</i>	<i>Tutorials</i>	<i>Exam</i>	<i>Written</i>	<i>C.A.</i>	<i>Oral</i>
2	18 h		X	X		
<i>Course outline:</i>						
<p>This course, entitled "History of Science and Technology in Society", takes an interdisciplinary approach in the humanities and social sciences (history, philosophy, sociology, political science) to the place of natural science and technology in society - past and present. The aim is to help Master's students take a step back from natural science and technology, and from the various issues involved in their deployment in society.</p> <p>The "History of Science and Technology in Society" course involves a graded assessment of students (1.5-hour final table exam).</p> <p>The following topics will be discussed:</p> <ul style="list-style-type: none"> <li>❑ Can we define "science"? What is a scientific "proof"? Illustration with the case of electromagnetic wave propagation (1888-1893).</li> <li>❑ What influence does the social and historical context have on the establishment of a scientific statement? What is scientific "truth"? An example of scientific controversy in society: spontaneous generation (1859-1864).</li> <li>❑ Is science gender biased? What has been the role of women within science?</li> <li>❑ What are the links between hydrocarbon energies (coal, oil) and democracy in the 19th and 20th centuries? How has oil gradually shaped the contemporary world?</li> </ul>						
<i>Learning outcomes:</i>						
<p>The aim of this course is to contribute to the training of future Master's graduates who do not have a naive view of natural science and technology, and who have a professional (and personal) awareness that is open to the causes and consequences of scientific practices.</p> <p>The course will develop students' critical thinking and intellectual autonomy.</p>						

# MASTER MATERIALS SCIENCE AND ENGINEERING

## TRACK M2 Materials for the future: Design and Engineering: MADI

<b>MAD-INNOV</b> <b>MANAGING THE UNKNOWN</b> <i>Tags: innovation, engineering, design</i>				
Responsible		Pascal Le Masson Pascal.le_masson@mines-paristech.fr		
ECTS	Course	Practicals/case studies	Exam	Written
3	15 h	15h	X	100%
<i>Course outline:</i>				
<p>This 30-hour face-to-face course, held during PSL Week in November 2024 (25.11 to 29.11), is an in-depth introduction to managing the unknown with the support of design theory. Contemporary issues of managing transitions (climate, energy, mobility, digital...) and managing crisis (pandemia, inflation, energy prices, war...) call for a capacity to organize collective action in the unknown – this capacity is expected from all kinds of managers, and in particular scientists, engineers, and designers. The capacity is today more easily acquired thanks to the advances in design theory. Design theory brings solid foundation for designing transition and designing resilient solutions to face contemporary crises. These approaches are essential today for those who wish to train in the management of innovation, scientific entrepreneurship, and the management of contemporary transitions.</p> <p>The course alternates between theoretical lessons in the morning and practical workshops in the afternoon. Practitioners are invited to speak about their experience of design in various areas (business, science, art).</p> <p>Main notions:</p> <p>In the end of the course, participants should have acquired the following capacities:</p> <ul style="list-style-type: none"><li>□ On design reasoning: capacity to build a simple C-K; capacity to evaluate a C-K (main notions: C-space, K-space, operators, double expansion)</li><li>□ On knowledge for generativity: capacity to learn and develop knowledge for generativity (main notions: independent knowledge, splitting knowledge)</li><li>□ On leadership for defixation: capacity to give relevant input to help team members to overcome their own fixation (main notions: fixations, defixation)</li><li>□ On economic evaluation in design: capacity to rely on economics criteria for improved exploration (main notions: design of decision, design for genericity, the value of knowledge in design activity)</li><li>□ On organization of collective design: capacity to rely on and make relevant use of R&amp;D capacities in companies, capacity to organize innovative design processes (main notions: organization principles of rule-based and innovative design, dominant design, KCP processes)</li><li>□ On design and ecosystems: introduction to “double impact” research and “mission-driven” companies.</li></ul>				

*Updated June 2024*

# MASTER MATERIALS SCIENCE AND ENGINEERING

## TRACK M2 Materials for the future: Design and Engineering: MADI

### Practical information

#### Host institution

Chimie ParisTech  
11 rue Pierre et Marie Curie  
75005 PARIS  
[www.chimie-paristech.fr](http://www.chimie-paristech.fr)

#### Teaching places

Most of the courses take place in the three engineering schools : Chimie ParisTech, MINES Paris, ESPCI Paris.

MINES Paris  
60 boulevard Saint-Michel  
75006 Paris  
[www.minesparis.psl.eu](http://www.minesparis.psl.eu)

ESPCI Paris  
10 rue Vauquelin  
75005 PARIS  
[www.espci.fr](http://www.espci.fr)

Part of the courses is common to the graduate engineering program of the partner schools.



# MASTER MATERIALS SCIENCE AND ENGINEERING

## TRACK M2 Materials for the future: Design and Engineering: MADI

### Contacts

#### ***Mention Materials Science and Engineering:***

Jolanta Swiatowska & Loïc Assaud, heads of MASTER SGM ([contact.master-sgm@psl.eu](mailto:contact.master-sgm@psl.eu))

<https://www.psl.eu/formation/master-sciences-et-genie-des-materiaux>

Alexandr Oshchepkov, head of MADI ([alexandr.oshchepkov@espci.psl.eu](mailto:alexandr.oshchepkov@espci.psl.eu))

#### ***Track MADI :***

- Elective E1 « Sustainable Energy & Materials » Armelle Ringuedé
- Elective E2 « Materials for Sustainable Lifestyle » Corinne Soulié
- Elective E3 « Engineering Resilient Materials for Transport and Structures » Cécilie Duhamel

#### ***Welcome Desk PSL:***

<https://psl.eu/vie-de-campus/services-etudiants/psl-welcome-desk>

welcomedesk@psl.eu / 01 75 00 02 91

The Welcome Desk helps international students for administrative procedures and boosts up their everyday life.

A bilingual team organizes different activities throughout the year. Touristic joggings, cultural visits...there is something for everyone! At these events international students meet other students, both internationals and Parisians who are part of the PSL network, improve their French and discover the different parts of Paris.

For more information, Facebook page: Welcome to Paris and to PSL!