Course Title**: Solid-State Chemistry and Nanomaterials**

ECTS	**University**	**Evaluation method**	**Number of hours**	**Mode of delivery**	**Learning outcome**
7	Marseille	Written exam 80% Lab work report 20%	63 h	Lecture (54 h) Lab Work (9h)	*The skills acquired at the end of the course:* - Describe and study the crystalline structure of materials - Select and optimize a protocol to elaborate inorganic solid nanomaterials according to given specifications. - Comprehend the relations between structure and properties

Prerequisites: general (inorganic) chemistry, basic physical-chemistry, basic thermodynamics.

Objectives: The objectives of this course is threefold: to describe and characterize the crystalline structure of bulk materials and to know the main techniques used for their elaboration, to overview the different conventional and emergent chemical methods applied to elaborate nanomaterials using bottom-up (and top-down) approaches and finally to comprehend the relations between structure and properties

Contents:

	Lecture	Lab Work
	n hours	*l hours*
Part 1: 1/ After a brief introduction on symmetry elements and operations, the structure of important classes of solids is developed: Metals simple close packed structures, Basic simple structures such as salts (CsCl, NaCl, CaF_2), oxides (Na_2O) and sulphides (ZnS) and more complex structures: carbon-based structures (graphite and diamond) and oxides (rutile, perovskite, layered perovskite, spinel). 2/ The second chapter focussed on X-Ray diffraction techniques. First the basics of X-Ray diffraction is presented then the acquired knowledge is applied on the study of crystalline structures using X-Ray diffraction patterns obtained on powders. 3/ The last chapter deals with the description of elaboration techniques that are conventionally used to prepare powders at micrometer scale.	27	
Part 2: 1/ Brief introduction on the unique properties of nanomaterials and their applications in the multiple domains of nanotechnology (environment, energy, medical, optics, lab-on-chip…). 2/ Chemistry involved in the synthesis of inorganic (metal oxides, metals, quantum-dots) nanostructured materials. Understand the various steps that lead to nanomaterials from molecular and/or supramolecular precursors. Condensation in solution, solid-state reactions, sol-gel chemistry, colloidal chemistry, surface functionalisation. 3/ Understand the Thermodynamic and kinetic controls over nucleation, growth, ripening, and self-assembly at the nanoscale. 4/ Describe the elaboration of model nanostructured materials including nanoparticles, nano-wires, nano-coatings, nanoporous	27	

materials, hierarchical nanomaterials, nanocomposites, and their properties and applications. 5/ Describe the potential combinations of these materials with "top-down" processes such as lithography, nano-imprint, micro-contact printing, selective etching to elaborate complex nanopatterns. Part 3: In order to comprehend the relations between structure and properties, a laboratory work will deal with the synthesis of materials both at micro- and nanometer scales, their characterization and the study of their properties. It will be associated to the reading of the more significant papers linked to the subject.	9h	

Recommended or required readings

Part 1:

SOLID STATE CHEMISTRY, An introduction, Lesley Smart and Elaine Moore
BASIC SOLID STATE CHEMISTRY, Anthony R. West

Part 2:

NANOCHEMISTRY, Geoffrey A Ozin and André C Arsenault
CONTROLLED GROWTH OF NANOMATERIALS, Lide Zhang, Xiaosheng Fang, Changhui Ye.

List of teachers: David Grosso, Prof. Aix-Marseille University (http://davidgrosso.wixsite.com/scientist-site) and Virginie Hornebecq, Associate Prof. (Aix-Marseille University)

Course Title: **Basic quantum chemistry modelling**

ECTS	University	Evaluation method	Number of hours	Mode of delivery	Learning outcome
3	Marseille	Written exam 60%; hands-on report 40%	27	Lecture, Computer Lab hours	*The skills acquired at the end of the course:* students will be able to select the appropriate methods in order to prepare, run and analyze a quantum chemistry calculation on a given system

Prerequisites: basic quantum mechanics, basis molecular chemistry

Objectives : The main goal of this course is to learn how to run a quantum chemical calculation and analyze its output. In order to achieve this, students will learn a) the underlying concepts of the different families of quantum chemical methods, b) how to prepare the input of - and run a quantum chemical calculation c) how to extract and analyze the useful information from the output of the calculation

Contents:

	Lecture	Lab Work
	n hours	*l hours*
1. The concept of potential energy surfaces (PES) : stationnary points, gradient vector, Hessian matrix, minimum energy path 2. What is needed in an input of a quantum chemical calculation ? z-matrix, spin multiplicity, basis set, electronic state, geometry optimization, frequency calculations, specific molecular properties 3. What is the method of choice to model my system ? Short review of quantum chemistry methods, their pros and cons	15	
4. Use of commercial quantum chemical softwares and graphical interfaces. The students will gain hands-on experience with performing quantum chemical calculations, and analyzing the results : a. Butterfly inversion in AX3 compounds b. Ring strain in small molecules c. Steric hindrance		12

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Recommended or required readings

Essentials of computational chemistry, Theories and Models, C.J. Cramer, Wiley.
Introduction to computational chemistry, F. Jensen, Wiley.
Computational chemistry : introduction to the theory and applications of molecular and quantum mechanics, E.G.Lewars, Springer

List of teachers:
D. Hagebaum-Reignier (http://ism2.univ-amu.fr/fr/annuaire/ctom/hagebaum-reignierdenis)
S. Humbel (http://ism2.univ-amu.fr/fr/annuaire/ctom/humbelstephane)

Course Title**: Computational modeling of nanosystems**

ECTS	University	Evaluation method	Number of hours	Mode of delivery	Learning outcome
7	Marseille	Written exam 50%; project report 50%	63	Lecture, Computer Lab hours	*The skills acquired at the end of the course: s*tudents will be able to start design, start and analyse molecular modeling projects

Prerequisites: general Physics, basic molecular chemistry

Objectives : The main goal of this course is to study the molecular dynamics and Monte Carlo methodology for atomistic numerical modeling. Introduction to the quantum ab initio methods.

Contents:

	Lecture	Lab Work
	n hours	*l hours*
1. Engineering computation applied to nanotechnology: Monte Carlo and molecular dynamics methods. Principles of molecular simulations. 2. Use open-source and commercial software. The students will gain hands-on experience with development of molecular dynamics and Monte Carlo codes, performing simulations, and analyzing simulation results. 3. The students will also learn to apply molecular simulation techniques for solving nanoengineering problems 4. Problem statements, selecting algorithms, writing computer programs, and analyzing output using Matlab (Scilab, Python).	24	39

Recommended or required readings
Understanding molecular simulations, D. Frenkel. B. Smith.
Molecular Modelling, A.Leach

List of teachers: B. Kuchta (http://madirel.univ-amu.fr/pages_web_KUCHTA_BOGDAN/infos)

Course Title**: Nano-engineering seminar + project**

ECTS	University	Evaluation method	Number of hours	Mode of delivery	Learning outcome
6	Marseille Wroclaw Rome	project presentation 100%	54	Students project	*The skills acquired at the end of the course:* students will be know the current rends in nanosicnce and technology

Prerequisites: general Physics, Chemistry and Material Science

Objectives: The main goal of this course is to understand the current trends and discoveries in the nanotechnology and its perspectives for applications in nanoengineering.

Contents:

	Lecture	Lab Work
	n hours	*l hours*
1. Introduction to nanoengineering; nanoscale fabrication: nanolithography and self-assembly; 2. Characterization tools; nanomaterials and nanostructures: nanotubes, nanowires, nanoparticles, and nanocomposites; 3. Nanoscale and molecular electronics; nanotechnology in magnetic systems; nanotechnology in integrative systems; 4. Nanoscale optoelectronics; nanobiotechnology: 5. Biomimetic systems, nanomotors, nanofluidics, and nanomedicine. 6. Synthesis techniques, processes, microstructural control, and unique physical properties of materials in nanodimensions. 7. Nanowires, quantum dots, thin films, electrical transport, electron emission properties, optical behavior, mechanical behavior, and technical applications of nanomaterials 8. Quantum mechanics in nanoelectronics. Wave mechanics, the Schroedinger equation, free and confined electrons, band theory of solids. 9. Nanosolids in 0D, 1D, and 2D. Application to nanoelectronic devices 10. Chemical principles involved in synthesis, assembly, and performance of nanostructured materials and devices. 11. Chemical interactions, classical and statistical thermodynamics of small systems, diffusion, 12. Carbon-based nanomaterials, supramolecular chemistry, liquid crystals, colloid and polymer chemistry, lipid vesicles, surface modification, surface functionalization, catalysis. 13. Principles of biochemistry tailored to nanotechnologies. 14. The structure and function of biomolecules and their specific roles in molecular interactions and signal pathways. 15. Nanoscale detection methods. 16. Understanding nanotechnology, broad implications, miniaturization: scaling laws; nanoscale physics;		54

Recommended or required readings

Review papers in Chemical reviews and the relevant papers in nano- journals

List of teachers: B. Kuchta (http://madirel.univ-amu.fr/pages_web_KUCHTA_BOGDAN/infos)

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Course Title**: Fundamentals of Nanophotonics**

ECTS	**University**	**Evaluation method**	**Number of hours**	**Mode of delivery**	**Learning outcome**
6	WrUST	Written exam 100%;	30	Lecture	*The skills acquired at the end of the course: s*tudents will become familiar with general concepts of nanophotonics

Prerequisites: general Physics, basic molecular chemistry

Objectives : The main goal of this course is providing an introduction into the areas of nanotechnology as employed in nanooptics, acquainting the students with measurement methods of nanophotonics and biophotonics and the application of those methods for bioimaging, therapies and for fabricating advanced miniaturized optical devices

Contents:

	Lecture	Lab Work
	n hours	*l hours*
1. Basic concepts of nanophotonics 2. Near field interactions and microscopy 3. Quantum confined materials 4. Plasmonics and nanoplasmonics 5. Nanocontrol of dynamics of excitations 6. Nanolithography 7. Photonic crystals and devices made out of them 8. Growth and optical characterization of nanomaterials 9. Molecular architecture in nanoscale 10. Nanophotonics for biotechnology and nanomedicine 11. Laser tweezers 12. Fundamentals of bioimaging and related techniques 13. Optical biosensors 14. Summary and discussion of selected issues	30	0

Recommended or required readings:

Review papers in high-end journals such as Nature Photonics

List of teachers: Prof. Marek Samoc

Course Title**: Synthesis and Fabrication of Nano-engineering Systems**

ECTS	**University**	**Evaluation method**	**Number of hours**	**Mode of delivery**	**Learning outcome**
3	Wrocław	In a form of poster	27	Lecture, Computer	*The skills acquired at the end of the course:* students will be able to understand how natural strategies for survival could be used in nanotechnology

Prerequisites: general Physics, basic molecular chemistry

Objectives: The main goal of this course is to study Biomimetics and Bioinspired approach in Nanotechnology.

Contents:

	Lecture	Lab Work
	n hours	*l hours*
1. Exploitation of means of survival used by certain organisms in designing new technologies. 2. Example of biomimetic system – construction of artificial photosystem. 3. Material science in regenerative medicine 4. Drug delivery and targeting 5. How design and engineer protein catalyst.	27	

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Recommended or required readings
Handbook of Biomimetics and Bioinspiration. Biologically-Driven Engineering of Materials, Processes, Devices, and Systems. Volume 1: Bioinspired Materials. Eds. : E. Jabbari, D.-H. Kim, L. P. Lee, A. Ghaemmaghami & A. Khademhosseini

List of teachers P. Kafarski (http://bioorganic.ch.pwr.wroc.pl/index.php/Main_Page)

Course Title**: Solid-State Chemistry and Nanomaterials**

ECTS	University	Evaluation method	Number of hours	Mode of delivery	Learning outcome
3	Marseille	Written exam 100%	30	Lecture	*The skills acquired at the end of the course:* Select and optimize a protocol to elaborate inorganic solid nanomaterials according to given specifications.

Prerequisites: general (inorganic) chemistry, basic physical-chemistry, basic thermodynamics, basic structure of materials.

Objectives : The objectives of this course is to overview the different conventional and emergent chemical methods applied to elaborate nanomaterials using bottom-up (and top-down) approaches.

Contents:

	Lecture	Lab Work
	n hours	*l hours*
1. Brief introduction on the unique properties of nanomaterials and their applications in the multiple domains of nanotechnology (environment, energy, medical, optics, lab-on-chip…). 2. Chemistry involved in the synthesis of inorganic (metal oxides, metals, quantum-dots) nanostructured materials. Understand the various steps that lead to nanomaterials from molecular and/or supramolecular precursors. Condensation in solution, solid-state reactions, sol-gel chemistry, colloidal chemistry, surface functionalisation. 3. Understand the Thermodynamic and kinetic controls over nucleation, growth, ripening, and self-assembly at the nanoscale. 4. Describe the elaboration of model nanostructured materials including nanoparticles, nano-wires, nano-coatings, nanoporous materials, hierarchical nanomaterials, nanocomposites, and their properties and applications. 5. Describe the potential combinations of these materials with "top-down" processes such as lithography, nano-imprint, micro-contact printing, selective etching to elaborate complex nanopatterns.	30	

Recommended or required readings
NANOCHEMISTRY, Geoffrey A Ozin and André C Arsenault
CONTROLLED GROWTH OF NANOMATERIALS, Lide Zhang, Xiaosheng Fang, Changhui Ye.

List of teachers: David Grosso, Prof. University Aix Marseille (http://davidgrosso.wixsite.com/scientist-site)

Course Title**: Organic chemistry of materials**

ECTS	University	Evaluation method	Number of hours	Mode of delivery	Learning outcome
3	Marseille	Written exam 60 %; project presentation 40 %	27	Lecture, practical exercices	*The skills acquired at the end of the course: s*tudents will be able to design synthetic schemes toward functional molecular architectures.

Prerequisites: general organic chemistry, aromatic chemistry chemistry

Objectives : The main goal of this course is to study the important reactions that are useful for the generation of π-conjugated materials and the functionalization of nanomaterials. Introduction to palladium-catalyzed coupling reactions and chemistry of nanocarbons.

Contents:

	Lecture	Lab Work
	n hours	*l hours*
1. Introduction on the properties and applications of π-conjugated nanomaterials, nanocarbons (fullerenes, carbon nanotubes, garphene) 2. Synthetic methods for the generation of functionalized oligomers and polymers with extended π-delocalization 3. Palladium-catalyzed cross-coupling reactions (Suzuki, Sonogashira, Heck) and amination reactions (Buchwald-Hartwig) 4. Addition reactions to fullerenes (1,3-dipolar cycloaddition, Bingel, nucleophilic addition). Covalent and non-covalent functionalization of carbon nanotubes and graphene. 5. Surface chemistry of inorganic nanoparticles (metals, metal oxides). 6. Application of "Click" chemistry in nanomaterials and dendrimers synthesis	19	3

Recommended or required readings
Review papers in Chemical Reviews and the relevant papers in journals of organic chemistry

List of teachers: F. Fages (http://www.cinam.univ-mrs.fr)

Course Title: **Structure and crystallography of solids**

ECTS	University	Evaluation method	Number of hours	Mode of delivery	Learning outcome
4	Wroclaw	Written exam 100%	30	Lecture	*Acquired skills at the end of the course:* students will become familiar with the structure of crystals and methods of studying crystals. It will also allow the students to understand information in crystallographic papers.
2	Wroclaw	Written test 100%	15	Classes	

Prerequisites:
General knowledge of mathematics, physics and chemistry.

Objectives:
The main goal of this course is to gain knowledge of (i) the structure, symmetry and diffraction of macro- and microcrystals, (ii) the structure, diffraction and properties of nanocrystals, (iii) methods of studies of macro-, micro- and nanocrystals, (iv) directions of development of crystallography and understanding crystallographic data in scientific papers.

Contents:

	Lecture	Classes
	n hours	*l hours*
1. The current definitions of crystals and crystallography. 2. The internal structure of crystals. A crystal lattice, lattice axes, lattice planes, a unit cell, Bravais cells. 3. The internal symmetry of crystals. Symmetry elements. Crystal systems. Space groups: international symbols and graphical representations. Examples of crystal structures. 4. Relationships between an internal structure and the external appearance of crystals. Crystal classes: international symbols & types. 5. A reciprocal lattice. Diffraction. Factors influencing the intensity of reflections. Diffraction pattern *vs* internal structure and symmetry of crystals. Single crystal X-ray structure analysis. 6. Synchrotron radiation: sources of the first, second, third and fourth generations & properties. 7. Microcrystalline materials: methods of crystallographic studies. Examples of crystallographic studies on microcrystals. 8. Nanocrystals. The quantitative and qualitative definition. The internal structure of nanocrystals vs. macrocrystals. Defects. External appearance. Properties. 9. Diffraction in nanocrystals. The broadening and shifting of peaks in powder diffraction patterns. Apparent lattice parameters: determination & influencing factors. 10. Synchrotron crystallographic studies of nanocrystals. 11. Neutronography and electronography *vs* roentgenography. Applications of these methods. 12. Crystallographic information in scientific papers.	30	15

Recommended readings:

[1] P. Luger, Modern X-Ray Analysis on Single Crystals, de Gruyter, Berlin, 2014.
[2] C. Giacovazzo, H. L. Monaco, G. Artioli, D. Viterbo, G. Ferraris, G. Gilli, G. Zanotti, M. Catti, Fundamentals of crystallography, C. Giacovazzo Ed., Oxford, 2011.
[3] International Tables for Crystallography, Volume A, Springer, 2005; Willey 2016.
[4] R. J. D. Tilley, Crystals and Crystal Structures, John Wiley & Sons Ltd, Chichester, 2006.

List of teachers:

Lectures: Ilona Turowska-Tyrk (ilona.turowska-tyrk@pwr.edu.pl)
Classes: Krzysztof Konieczny (krzysztof.konieczny@pwr.edu.pl)

Course Title**: Nanostructures in industrial and Numerical applications**

ECTS	University	Evaluation method	Number of hours	Mode of delivery	Learning outcome
4	Wroclaw	project	60	Computer modeling	*Acquired skills at the end of the course:* students will become familiar with wide range of applications for numerical modeling of nanosystems.

Prerequisites*:*
General modeling methods.

Objectives:
-To teach practical implementation of molecular modeling in the industrial applications.
-To access which property can be calculated and optimized using molecular modeling approach
-To teach how to adjust the method and the model to the given problem
-To teach practical implementation of data analysis
-To teach how to draw conclusions from molecular modeling experiment and implement them in the real case scenario.
-To teach how to run scientific projects within small groups.

Contents:

	Lecture	Classes
	n hours	*l hours*
Module overview: The idea of the module is to perform a simulation of a product development using molecular modeling approach. Thus students go through following scenario: 1. Formation of project groups min. 2 max 3 people. 2. Choice of project. 3. Preparation of research proposal including summary of the problem, goal and methodology. 4. Preparation of the project management plan including tasks, workload, critical path, rescue scenario. 5. Calculations. 6. Data analysis. 7. Formulation of solutions. 8. Oral presentation of the result. 9. Preparation of the project report in the form scientific paper. Sample projects: 1. Rational Design of surfactants for floatation purposes (QM, MD, MC) 2. Rational Design of hydrophobic-hydrophilic surfaces (QM, MD). 3. Pharmaceutical Crystallization and Formulation (QM, BCF). 4. Optimization of Corrosion Inhibitors (QM, MD). 5. Polymers miscibility, optimization of mechanical and structural properties of different polymer systems (MD, Flory-Huggins, CG) 6. Gas Capture and Storage (QM, MD, MC). 7. Optimization of membrane permeation properties (MD).		60

Recommended readings:

List of teachers:

Course Title**: Economics and Management**

ECTS	University	Evaluation method	Number of hours	Mode of delivery	Learning outcome
5	Wrocław	Written exam 100%	60	Lecture (30 h) classes (30 h)	*The skills acquired at the end of the course:* - prepare the budget and evaluate the financial present or future situation of an organization or project - plan and control the implementation of projects. - apply selected formal decision models to managerial decision making

Prerequisites: none

Objectives: The objectives of this course is threefold: to present basic accounting notions, like budget, revenues, expense, cash flow etc., to overview basic methods and techniques of project management and to introduce selected management science formal models which may help to make multicriteria managerial decisions.

Contents:

	Lecture	Lab Work
	n hours	*l hours*
Part 1: 1/ Basic accounting notions like revenues, expenses, cash flow, budget, balance sheet, loss and profit statement and cash flow statement will be presented and illustrated with examples. 2/ Expenses will be analysed in a deeper way: the difference between fixed and variable cost as well as between direct and indirect cost will be explained. Then it will be shown how the behaviour/type of cost influences the results of various decisions. 3/ The students will be familiarised with the evaluation of long term investments. They will learn how to incorporate in long term decision making the cost of capital and various types of risk and uncertainty.	10	10
Part 2: 1/ Basic steps of project initiation, planning and implementation will be illustrated. Students will learn how to formulate the goals of the project, to define its scope and to elaborate the project budget and schedule. Then they will be told how to control the project implementation and deal with changes. 2/ A special emphasis will be put on risk management. Methods and techniques of its identification, evaluation and mitigation will be discussed. 3/ The importance of the human aspect of project management will be underlined. Methods of project team members evaluation and motivation will be sketched.	10	10
Part 3: Selected formal models from management science which help to make managerial decisions will be presented. A special emphasis will be put on multicriteria decision making, applied to the selection of		

projects team members, projects, suppliers etc. Fuzzy numbers and their usefulness for making decisions under risk and uncertainty will be discussed.	10h	10h

Recommended or required readings
Part 1:
Managerial Accounting For Dummies, Mark P. Holtzman, Wiley and Sons 2013

Part 2:
Project Management For Dummies, Stanley E. Portny, Wiley and Sons 2013

Part 3 :
Decision Making For Dummies, Dawna Jones, Wiley and Sons 2014

List of teachers: Dorota Kuchta, Wroclaw University of Science and Technology.

Course Title**: ELECTROCHEMISTRY**

ECTS	University	Evaluation method	Number of hours	Mode of delivery	Learning outcome
7	Marseille	Written exam 100%;	54	Lecture, Lab hours	*The skills acquired at the end of the course:* students will be able to understand the main principles of electrochemistry and apply them to nanomaterials (synthesis and characterization)

Prerequisites: general chemistry.

Objectives: The main goal of this lecture is to acquire the basics of electrochemistry and electrochemical methods. The inetrest of electrochemistry in the field of nanoengineering will be demonstrated trough examples in nanosynthesis and characterization.

Contents:

	Lecture	Lab Work
	n hours	*l hours*
1. Electrochemistry basics: thermodynamics and kinetics applied to electrochemistry 2. Experimental approach of electrochemistry: steady state and transient methods (voltametry, chronopotentiometry, chronoamperometry, pulse methods...), impedance spectroscopy. 3. Application to the synthesis and characterization of nanomaterials (nanoparticles, nanostructured surfaces...)	48	6

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Recommended or required readings

BARD / ALLEN : Electrochemical Methods: Fundamentals and Applications
Pierre FABRY : Electrochemistry: The Basics, With Examples

List of teachers: C. Lebouin, F. Vacandio

Course Title: **Thermodynamics of Materials, Intermolecular and Surface Forces**

ECTS	University	Evaluation method	Number of hours	Mode of delivery	Learning outcome
3	Marseille	Written examination: theoretical questions and exercises	27	Lecture, Exercices	Students will be able to understand bonds in solids and use defect engineering for the tuning of properties

Prerequisites: basic chemical thermodynamics

Objectives: Knowledge of basic aspect of thermodynamics. Quantitative understanding of the different intermolecular forces between atoms/ions and molecules at the nanoscale level.

Contents:

	Lecture *hours*	Exercices *hours*
1. Fundamental laws of chemical and materials thermodynamics (principles, state functions, chemical potential, reference states, activity…) 2. Basic theory of bonds and modeling of interactions: quantitative understanding of the different intermolecular forces between atoms/ions and molecules and how these interactions can explain materials properties and interesting phenomena at the nanoscale (quantum size effects, wetting, self-assembly…) 3. Crystal defects: point defects, dislocations, surfaces and interfaces, defect engineering	24	3

Recommended or required readings
Basic Solid State Chemistry, A. R. West, Wiley
Physical Chemistry of Ionic Materials, J. Maier, Wiley

List of teachers: Philippe Knauth (http://madirel.univ-amu.fr/pages_web_KNAUTH_PHILIPPE/annuaire)