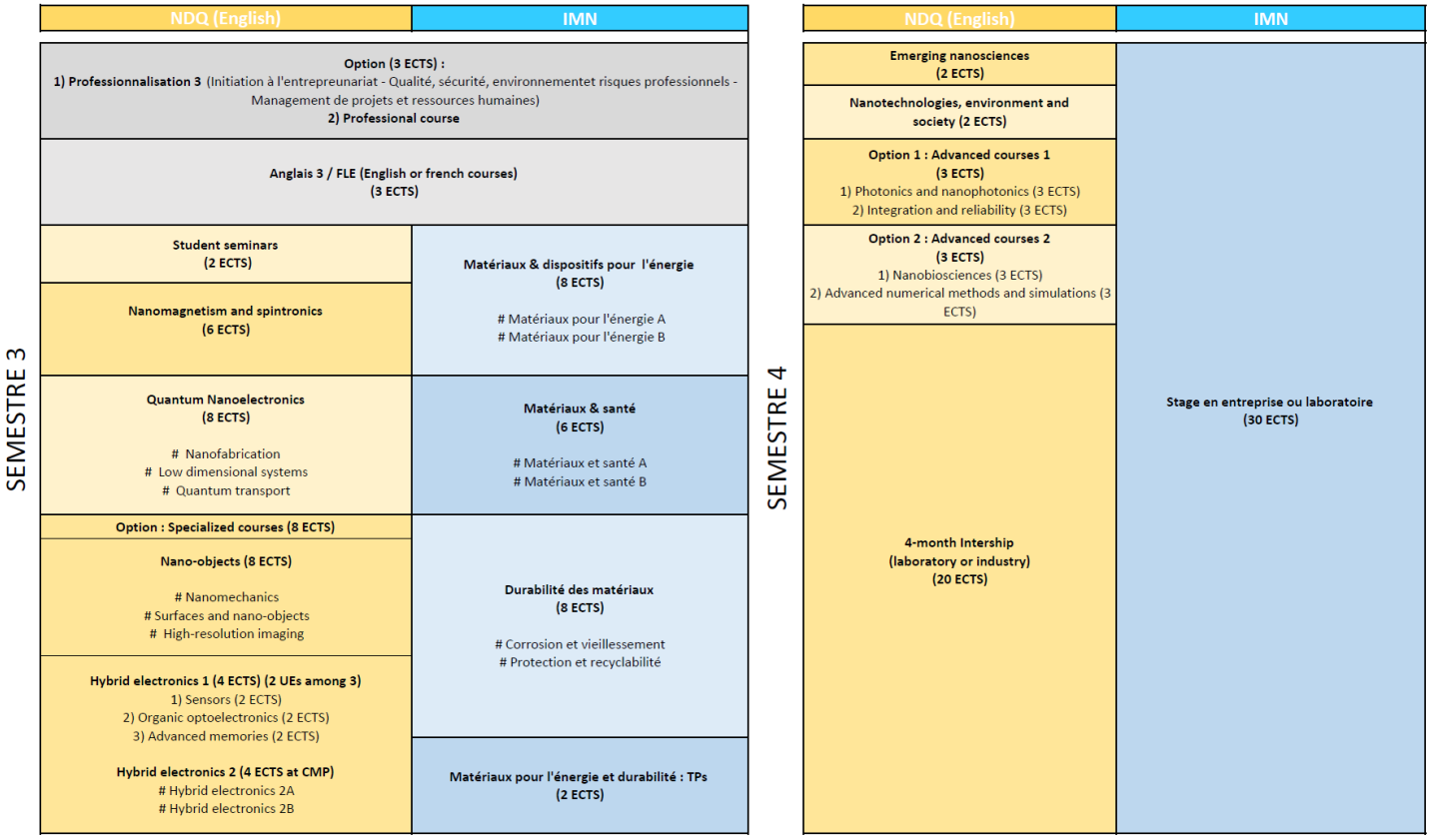
Master Nanosciences and Nanotechnologies

Overview of the M2 program (semesters 3 and 4)

« Nanoscale and Quantum Engineering »



Description of the courses of the M2 program « Nanoscale and Quantum Engineering »

Acronyms :

- UE : Teaching unit
- CM : Lectures
- TD : Tutorials
- TP : Practical works
- MCC : Student evaluation

SEMESTER 3

Optional course :

UE « Professionnalisation 3 » or « UE Professional course »

1) UE « Professionnalisation 3 » (in french, S3, 3 ECTS, UE à Choix)

L'étudiant pourra choisir 1 des 3 Unités d'Enseignement suivantes :

a. UE « Initiation à l'entrepreneuriat : droit du travail, éthique professionnelle et propriété intellectuelle »

Responsable : Virginie Hornebecq (MADIREL, Virginie.Hornebecq@univ-amu.fr)
18 h
Contenu : - Maitriser les connaissances de base en droit du travail - Comprendre les aspects éthiques du contexte professionnel - Connaître les différentes règlementations et les enjeux de la propriété intellectuelle
MCC : *Examen Terminal*

b. UE « Management de projets et ressources humaines »

Responsable : Virginie Hornebecq (MADIREL, Virginie.Hornebecq@univ-amu.fr)
18 h
Contenu : - Maitriser la méthodologie de gestion de projets - Maitriser les connaissances de base des relations managériales et des différents styles de management
MCC : *Contrôle continu, Examen Terminal*

c. UE « Qualité, Sécurité, Environnement et risques professionnels »

Responsable : Virginie Hornebecq (MADIREL, Virginie.Hornebecq@univ-amu.fr)
18 h
Contenu : - Maitriser les connaissances de base et les enjeux de la qualité et du management de la qualité - Maitriser les connaissances de base de l'environnement réglementaire (code du travail, sécurité, CHSCT) - Maitriser les connaissances de base et les enjeux des risques professionnels
MCC : *Contrôle continu*

2) *UE Professional course (in english, S3, 3 ECTS)*

Contact : to be precised
20h TD
Contents: *soon*
MCC : *soon*

UE « English or French courses » (S3, 3 ECTS)

Contact : Fidel Martinez (Aix-Marseille Université, Fidel.Martinez@univ-amu.fr) Service des Langues UFR Sciences (https://sciences.univ-amu.fr/service-langues)
18h TD
Contents : *Practice of English or French*
MCC : *On-going Evaluation, Final Exam*

UE « Student seminars » (S3, 2ECTS)

Contact : Conrad BECKER (CINaM, conrad.becker@univ-amu.fr)
18h TD
Contents : *Introduction to the preparation of scientific presentations.* • *Introduction to oral scientific presentation* *Students will learn how to* *construct a scientific presentation* *clearly present a topic* *capture the attention of the audience* *respect the timing* • *Interaction and support* *Students will give short presentations on selected topics with immediate feedback in order to ameliorate their presentation skills* • *Student oral presentations* *Finally, students will use the acquired skills to prepare an oral presentation on an imposed topic*
MCC : *Oral presentation*

UE « Nanomagnetism and spintronics » (S3, 6 ECTS)

Contact : Michael KUZMIN (IM2NP, michael.kuzmin@univ-amu.fr)

24h CM, 30h TD

Contents :

First part:

Introduction to the magnetic properties of materials, basics of magnetism at the atomic scale, ferromagnetism models and application to nanomaterials.

Second part:

Magnetism in low dimensional systems (ultrathin films) and interlayer coupling in heterostructures, spin transfer and spin transport in nanostructures and their applications (magnetoresistive sensors (GMR), STT-MRAM, spin transfer nano-oscillators), techniques for the creation and detection of spin current (spin pumping, inverse spin Hall effect).

Topics :

- *Nanomagnetism: dia- and paramagnetism, antiferromagnetism, ferromagnetism (mean-field theory, Heisenberg model), magnetic anisotropy, magnetic domains (Kittel's theory), hysteresis, nanoparticles (monodomain) and ferromagnetic nanowires, magnetic recording, magnetic resonance, magnetic measurements.*
- *Spintronics: magnetism in ultrathin films and heterostructures (anisotropy, non-colinear magnetic configurations, DMI, interlayer exchange coupling, exchange bias), giant magnetoresistance, tunnel magnetoresistance (applications), injection, spin accumulation and relaxation in metals, spin Hall effect, spin transfer torque).*

MCC : *On-going Evaluation, Final Exam*

UE « Quantum Nanoelectronics » (S3, 8 ECTS)

EC « Nanofabrication »

Contact : Luc FAVRE (IM2NP, luc.favre@univ-amu.fr)

9h CM, 4h TD, 12h TP

Contents :

Description of Top-Down technics for the nanofabrication:

- *Definition and history of the Top-Down approach. Comparison with the Bottom-up approach: avantages and disavantages.*
- *Lithography: main principles, optical lithography (DUV, EUV, RX), electronic lithography, ion etching*
- *Nanoimprint, nanomolding, nanostamp*
- *Scanning probe microscopy patterning: AFM & STM*

Some of these technics will be studied in practical works, together with growth processes and characterization technics: CVD, RTP, ion etching, MBE, Dip-Coating, nanoimprint, laser ablation, field electron emission.

Topics :

- *Top-Down technics*
- *CVD, RTP, ion etching: fabrication of ordered quantum*
- *EJM : fabrication of strained layers SiGe/Si*
- *Sol-Gel : fabrication of anti-reflective layers*
- *Laser ablation*
- *Field electron emission (Fowler-Nordheim's law)*

MCC : *On-going Evaluation, Final Exam*

EC « Low dimensional systems »

Contact : Nicolas CAVASSILAS (IM2NP, nicolas.cavassilas@univ-amu.fr)

18h CM + 9h TD

Contents :

This course will provide students with the concepts and methods to understand from which originate the peculiarities of low dimensional systems, and how systems of low dimensionality, by generating quantum phenomena, can be useful for the components used in the fields of nanoelectronics. The considered quantum behaviors are the confinement, the hoping, the tunneling, the interferences… and will be applied to ultimate transistors, light-emitting diode, third generation solar cells.

MCC : *On-going Evaluation, Final Exam*

EC « Quantum transport »

Contact : Fabienne MICHELINI (IM2NP, fabienne.michelini@univ-amu.fr)

18h CM + 9h TD

Contents :

This course is divided in two parts.

- *The first part starts with semi-classical theory (drift-diffusion), scattering (phonon, impurities...), recombination (radiative, Auger…), low perturbation simplifications (diffusion, mobility), high field, to reach ballistic quantum transport (low dimensional system), transmission in different systems.*
- *This more fundamental part targets to give the methodological basics for addressing the quantum transport in interacting out-of-equilibrium nanosystems, from Landauer formalism to Green's function method.*

MCC : *On-going Evaluation, Final Exam*

UE « Optional course: Specialized courses » (S3, 8 ECTS)

1) Nano-objects

EC « Nanomechanics »

Contact : Olivier THOMAS (IM2NP, olivier.thomas@univ-amu.fr)
18h CM, 8h TD
Contents : *This course aims to provide the basis to understand the mechanics of nano-objects. It is intended for students wishing to acquire basic knowledge of solid mechanics and its applications to nanostructures.* *Topics :* • *Introduction* • *Continuum elasticity* • *Introduction to the theory of dislocations* • *Elastic theory of dislocations* • *Movement of dislocations* • *Mechanics of nano-objects*
MCC : *On-going Evaluation, Final Exam*

EC « Surfaces and nano-objects »

Contact : Pierre MÜLLER (CINaM, pierre.muller@univ-amu.fr)
18 CM, 8h TD
Contents : *This course is an introduction to the physics of surfaces, interfaces and nano-objects adsorbed on surfaces: description, dynamics, growth mechanisms, morphology, stability,…* *Topics :* • *I/ Surfaces: Description (direct and reciprocal spaces), Statics, Dynamics, Nanostructuration, Properties, ...* • *II/ Growth mechanisms: basic laws, BCF model, 2D and 3D nucleation, Growth spiral, Epitaxy, Growth modes, Instabilities, Bottom-up…* • *III/ Structure, Morphology et Stability of nano-objets : Wulff construction, Wetting/Dewetting, Ripening/Coalescence, Stability/Fluctuations of shape and composition…* • *IV/ Properties of nano-objets: Typical dimensions, Classical size effect (1/r), Confinement effects…*
MCC : *On-going Evaluation, Final Exam*

EC « High-resolution imaging »

Contact : Laurent NONY (IM2NP, laurent.nony@univ-amu.fr)

6h CM, 20h TP

Contents :

This course concerns the characterization of nanostructures by:
1) near-field microscopy: scanning tunneling microscopy (STM) and atomic force microscopy (AFM)
2) electron microscopy: high resolution transmission electron microscopy (HRTEM) and low energy electron microscopy
The training is focused on the practical implementation of these techniques via lab tests on lab instruments in small groups of students. The aim of this course is to give basic practical and theoretical skills to understand and implement the operating modes of theses microscopes. Students will also have to master the characterizations to which these types of microscopies give access (resolution, origin of the contrast ...).

Topics :

- *Introduction to near field microscopy (STM & AFM) : Concepts; key elements; STM (tunnel current, resolution, spectroscopy); AFM (tip-surface forces, dynamic modes, resolution, specificities related to the environment)*
- *Introduction to electronic microscopies (LEEM & HRTEM) : Optics for electrons, Fourier optics; Theory for the formation of images, methods for image simulation, Analysis technics*
- *Practical work: STM and tunnel spectroscopy in UHV environment*
- *Practical work : AFM in liquid cell: characterization of biological nanostructures*
- *Practical work : Non-contact AFM in UHV environment: characterization of inorganic nanostructures and thin films. Advanced methods (Kelvin probe).*
- *Practical work : LEEM: in-situ characterization of a phase transition (dark and bright fields)*
- *Practical work : HRTEM: Quantitative analysis of the contrast (structure and deformations)*

MCC : *On-going Evaluation, Final Exam*

2) Hybrid electronics

Hybrid electronics 1 (4 ECTS, S3)

2 EC have to be chosen among 3 EC:

EC « Sensors »

Contact : David GROSSO (IM2NP, david.grosso@im2np.fr)

12h CM, 6h TD

Contents :

This course describes the different families of sensors (i) physical (temperature, pressure, speed ...) (ii) chemical (gaseous, liquid, solubilized compounds), and (iii) biological (biomolecules, enzymes, antibodies, etc.) and the different transduction modes (optical, electrical, mechanical ...) associated. The different methods of elaboration of sensitive materials and devices are also briefly discussed.

Topics :

- *Physical sensors*
- *Biological sensors*
- *Chemical sensors*

MCC : *Final Exam*

EC « Organic optoelectronics »

Contact : Judikaël Le ROUZO (IM2NP, judikael.le-rouzo@univ-amu.fr)

12h CM, 6h TD

Contents :

This course will present the current components of organic optoelectronics (OLEDs, Laser, Solar cells). An introduction to organic semiconductors will be made. A presentation of the different physical phenomena will allow to understand the functioning of the components. Recent examples of architecture and / or performance of the devices will be studied.

Topics :

- *Organic semiconductors*
- *Organic Photonic*
- *Optoelectronic organic devices (architecture/optoelectronic behavior/performances)*

MCC : *Final Exam*

EC « Advanced Memories »

Contact : Philippe CHIQUET (IM2NP, philippe.chiquet@univ-amu.fr)

12h CM, 6h TD

Contents :

This course offers a detailed study of the main families of memory devices, present in current technological objects. Once the economic / industrial context related to this type of components is presented, a state of the art will identify the main memory devices. Their operating mode will then be detailed, with the description of the underlying physical phenomena.

Topics :

- *General notes on memory devices : the economic / industrial context, main families of memory devices, main characteristics*
- *Volatil memorie*
- *Traditional non-volatil memories : Flash, EEPROM, …*
- *Advanced non-volatil memories: resistive, ferroelectric, magnetic memories, with organic components*
- *Study of a specific memory device (to be choosen)*

MCC : *On-going Evaluation, Final Exam*

Hybrid electronics 2

EC « Hybrid electronics 2A »

Contact : Thierry DJENIZIAN (CMP, thierry.djenizian@emse.fr)
12h CM, 6h TD
Contents : *This course is dedicated to the principle of electrochemical energy storage for flexible microelectronics. It will be presented recent progress achieved in the field of Li-ion microbatteries. The principles will be explained in terms of basic electrochemistry and thermodynamics. The relationship between properties at the atomic level with the performance of the power sources will be highlighted. Particularly, an insight into the use of nanostructured materials to improve the storage capacity, rate capability, and cyclability will be given.* *Seminars on microfabrication will be given by foreign professors from renowned universities is dedicated to the microfabrication processes. It will be presented recent progress achieved in the field of microtechnologies (high resolution patterning techniques, self-assembly processes, atomic layer deposition techniques, etc.). Particularly, an insight into micropatterned surfaces will be given for modern applications including sensors, biosensors, energy production and storage systems, lab-on-a-chip, smart devices...*
MCC : *Final Exam*

EC « Hybrid electronics 2B »

Contact : Thierry DJENIZIAN (CMP, thierry.djenizian@emse.fr)
12h CM, 6h TD
Contents *Electronic devices have evolved from rigid, planar, and packaged formats into highly flexible, curvilinear and unpackaged physical designs. Rapid development of soft/stretchable inorganic/organic electronics, wireless communication modules, biosensors, and soft encapsulating substrates underlies this ascension in recent years. As a result, we have observed advances in system level mechanics with implications for emerging biomedical devices, human-machine interface designs, e-skins, prosthetics, surgical/nonsurgical robotics, plastronics and flexible optical instruments for imaging and telecommunication. After more than two decades of academic and industry research, this new class of electronics is poised to have commercial impact. During this class, we will detail the different fabrication techniques, characterization and applications of this new kind of electronic devices.*
MCC : *Final Exam*

SEMESTER 4

UE « Emerging nanosciences» (S4, 2 ECTS)

Contact : Conrad BECKER (CINaM, conrad.becker@univ-amu.fr)
18h CM
Contents : *Specialized courses on current topics related to nanoscience, presented by different researchers from AMU or other institutions.* • *Introduction to the different domains of nanoscience* • *Emerging topics in nanoscience: definition, examples of topics, industrial applications of nanoscience* • *Specialized courses*
MCC : *Final Exam*

UE « Nanotechnologies, environment and society » (S58PR4M3, S4, 2 ECTS)

Contact : laurence.masson@univ-amu.fr
18h CM
Contents : *Courses given by external teachers exposing the state of the art in terms of the industrial, economic, environmental, human health impacts of nanotechnologies and the current legislation for nanomaterials.*
MCC : *Final Exam*

UE « Optional course: Advanced courses 1 » (S4, 3 ECTS)

1) UE « Photonics and nanophotonics » (3ECTS)

Contact : Gilles RENVERSEZ (Inst. Fresnel, gilles.renversez@univ-amu.fr)
18h CM, 9h TD
Contents : *Basics of optical wave guide, plasmonics and photonics.* *Topics :* • *Introduction and analogy between electromagnetic waves and quantum mechanics for electrons* • *Basics of optical wave guide* • *Photonic crystals* • *Microresonators, microcavities, microsources and other photonic devices* • *Overview of the use non-linear optics in photonics*
MCC : *On-going Evaluation, Final Exam*

2) UE « Integration and reliability » (3ECTS)

Contact : Jean-Luc AUTRAN (IM2NP, jean-luc.autran@univ-amu.fr)
18h CM, 9h TD
Contents : *This course is an introduction to the issues of component integration in Ultra Large Scale Integration (ULSI) microelectronics and the electrical and radiative reliability of advanced CMOS technologies. The integration and reliability aspects will be addressed through a description of the physics of the components and the physical phenomena that govern i) the reduction of the dimensions of the devices at the deca-nanometer scale and ii) their sensitivity to the mechanisms of electrical degradation or induced by radiation, natural or artificial.* *Topics :* • Evolutions and integration rules of components in microelectronics ULSI • *Electrical reliability of advanced CMOS technologies* • *Radiation effects and radiative reliability of advanced CMOS technologies*
MCC : *On-going Evaluation, Final Exam*

UE « Optional course: Advanced courses 2 » (S4, 3 ECTS)

1) UE « Nanobiosciences » (3ECTS)

Contact : Stéphane GRIMALDI (BIP, stephane.grimaldi@univ-amu.fr)
18h CM, 9h TD
Contents : *This course aims at showing how the concepts and techniques of nanosciences can be used to describe biological system functions at the nanometer scale and to derive potential applications. Particular emphasis will concern energy capture and storage mechanisms and their interconversions: light, chemical and mechanical energy, information transfer.* *Topics :* • *I- Introduction to nanobiosciences* • *II-* Analysis of main energy conversion and storage systems - Bioenergetics • *III- Conversion of chemical and mechanical energy* • *IV- Conversion of energy into information transfer*
MCC : *On-going Evaluation, Final Exam*

2) UE « Advanced numerical methods and simulations » (3 ECTS)

Contact : Fabienne MICHELINI (IM2NP, fabienne.michelini@univ-amu.fr)
9h CM, 18h TP
Contents : *This course is an introduction to HPC (High Performance Computing): paradigms and application to nanosciences and nanotechnologies It follows up the courses of Numerical Simulations proposed in the first year of the master. Students will program in Fortran or any equivalent basic language using MPI libraries, on a cluster architecture of the mesocenter of Marseille.* *Topics :* • *Paradigms of parallel programming* • *HPC architectures* • *Applications to problems of nanosciences and nanotechnologies*
MCC : *On-going Evaluation, Final Exam*

UE « Intership in laboratory or enterprise» (20 ECTS)

Contact : Fabienne MICHELINI (IM2NP, fabienne.michelini@univ-amu.fr)
4 months
Contents : 4 month internship (laboratory or industry)
MCC : *Master thesis, evaluation by the supervisor, oral presentation*