

Double Masters in Mechanical Engineering and Materials Engineering

The International "Nanosciences" and "Materials Engineering" Master programs in Normandy allow you discovering state-of-art research laboratories, establishing a widespread network of international connections and discovering the French and specifically the Normand way of life.

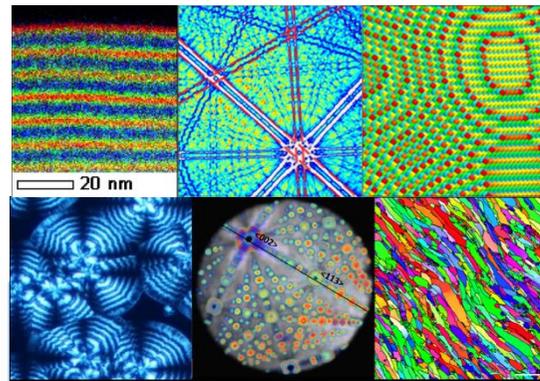
During your one-year stay in Rouen:

- Classes will be taught in English by academics and industrial specialists
- Students will have a personal tutor/advisor
- Students will apply for a granted 6-months internship in a research laboratory or in industry.

Motivated and selected candidates will gain, at the end, a unique and exciting experience validated by a Double Diploma from both Rouen-Normandie and Nebraska-Lincoln Universities.

Job opportunities

Students graduating the Double Master program can be either recruited in the industry as executives, middle managers or engineers (*project managing, research and development, production of metals and alloys, plastics, nano-materials, materials control and characterization...*) or enrolled in a PhD program aiming to academic positions (professor, researcher...).



M2 Materials engineering

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M2 Nanosciences

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International exchanges

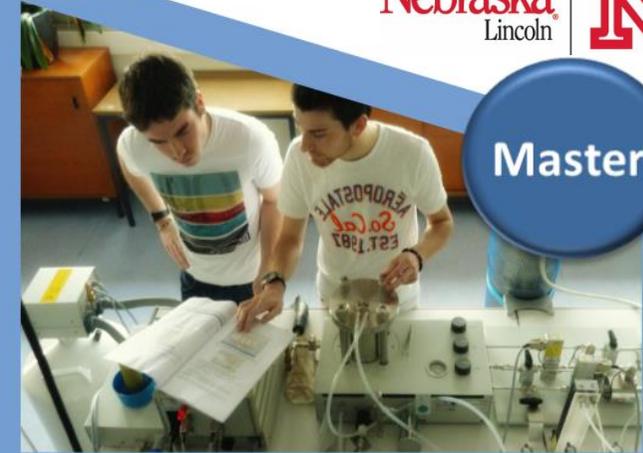
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Double Masters in Mechanical Engineering and Materials Engineering



Master

Matter sciences

International training programs

- Materials engineering
- Nanosciences



Purposes

"Matter Sciences" is an international master program built on laboratory knowledge and skills. Our students are:

- Directly recruitable

- Able to go on with a PhD program

After the master program, our students have solid knowledge and skills about:

- The relations between physical properties and microstructure

- The mechanisms of materials ageing

- The techniques to characterize, measure and monitor materials properties and microstructures

- The numerical tools for materials science

- English and French (for both daily and scientific uses)

- The management of R&D projects

Students in materials science and engineering develop an understanding of materials at the nano, micro and macro scales, leading to specialization in such topics as: nuclear, polymers, composites, magnetic and optical materials; computational materials science and engineering.

The training programs

Students can select a specific training program:

Materials engineering: engineering polymer and metal alloys (●)

Nanosciences: innovating metal alloys and nano-materials (●)

The choice of a training program is determined by the choice of specific classes during the year of the master program. **A total of 60 European Credits EC must be chosen (45 +15 for the internship) from the following list:**

(more details at <http://gpm.univ-rouen.fr/en/node/71>)

S1 sept to dec

Thermodynamics (5 EC)

- Statistical thermodynamics
- Thermodynamics of solid solutions

Materials Structure (6 EC)

- From perfect to real crystal
- Atomic physics

Materials properties 1 (6 EC)

- Linear elasticity
- Physics of the solid state 1
- Hyper-elasticity, viscoelasticity, damage of polymers

Diffusion and phase transformations (6 EC)

- Diffusion in the solid state
- Phase transformations 1

Business and employability (2 EC)

- Knowledge of business, Management
- Technological survey, Intellectual property

Numerical methods (6 EC)

- Monte Carlo simulation, Phase field methods
- Industrial numerical methods (DAO/CAO – Thermocalc)

Polymers physics (11 EC) ●

- Polymers, plastics and plastic manufacturing
- Fundamentals about amorphous materials and glasses
- Polymer ageing and degradation
- Biopolymers et biocomposites
- Nanostructured polymers
- Semicrystalline polymers

Physical metallurgy (11 EC) ● ●

- Corrosion
- Mechanical degradation
- Phase transformations 2
- Materials exposed to radiation
- Symmetries

Physics of nanomaterials (11 EC) ●

- Elaboration and analyse of nanomaterials
- Magnetism
- Nanomagnetism
- Solid state physics and radiation-matter interaction
- Nano-optics and nanoelectronics

Foreign languages (2 EC)

- French

S2 dec to march

Industrial materials (8 EC)

- Metals and metallic alloys
- Polymers

Materials properties 2 (7 EC)

- Properties of macromolecular materials

- Relationship between microstructure and plasticity in metals

Physics of condensed matter (8 EC)

- Physics of the solid state 2
- Magnetic and dielectric properties

Foreign languages (2 EC)

- French

Characterization techniques (12 EC)

- Microscopy, Spectroscopies, Atom probe, Thermal analysis...
- R&D case study

Business and employability (3 EC)

- Employability
- Standards and quality

Internship /duration : 6 months March to Aug (15 EC)

- Laboratory or company, France or abroad



Master Degree – Matter Sciences

Details on Training Programs

Thermodynamics

- Statistical thermodynamics

I. Background

Introduction

Accessible states (microscopic states)

Statistical ensembles

Ergodicity

Statistical entropy

Micro-canonical ensemble (entropy, spontaneous evolution of an isolated system, definition of temperature)

II. Canonical ensemble

Introduction

Canonical probability distributions (Gaussian approximation)

Internal energy, free energy, entropy, application to the monoatomic ideal gas

Heat capacity, pressure and chemical potential, application to the monoatomic ideal gas

Spontaneous evolution of the system (thermodynamic potential in the canonical ensemble)

III. Grand canonical ensemble

Introduction

Grand canonical probability distributions (Gaussian approximation)

Grand potential

Average number of particles and internal energy

Entropy and pressure

Application to the monoatomic ideal gas

Spontaneous evolution of the system

- Thermodynamics of solid solutions

This course deals with some of the thermodynamic concepts that are required for the fundamental understanding of phase diagrams and phase transformations.

Chapter I: Basics concepts of thermodynamic

Chapter II: Phase diagrams of pure elements

Chapter III: Binary phase diagrams

I-Systems of perfect miscibility

Phase diagrams, ideal solid solution model

II-Systems with a miscibility gap

Phase diagrams, regular solid solution model

III-Systems showing an ordering tendency

IV-Eutectic and eutectoid reactions

V-Peritectic and peritectoid reactions

VI-Monotectic and monotectoid reactions

Chapter IV: Ternary phase diagrams

Materials Structure

- From perfect to real crystal

Introduction: influence of defects on properties of materials

Point defects: impurities, vacancies, interstitials

 Energetic of point defects

 Point defects concentrations

Dislocations

 Experimental evidence

 Slip systems (BCC, FCC, HCP)

 Schmid and Boas 's law

 Dislocations properties

 Perfect and imperfect dislocations

 Stacking fault, twins, energetic

Interfaces and Grain Boundaries

 Free surface, energy, Wulff construction

 Nanoparticles

 Grain boundaries, tilt, twist

 Interface interphases (coherent, semicoherent, incoherent), misfit, energy

- Atomic physics

Physics of Atoms and introduction to nuclear physics

Introduction to Quantum Mechanics, Probability Amplitudes and Quantum States, Postulates

Dirac Notation and the Energy Representation,

Spin Angular Momentum, SE

Hydrogen atom

Hydrogen spectral series

Zeeman effect

Stark effect

Nuclear models (the collective model, shell model)

Radioactivity

Fusion and fission

Materials properties 1

- Linear elasticity

Introduction: why elasticity is important, elastic deformation

Microscopic origin of elasticity

Experimental evidence of elasticity

 Uniaxial tension test, Young modulus, Poisson ratio, shear modulus, Compression

Theory of elasticity

 Tensors, stress and strain, shear, torsion, Hooke's law

Thermodynamic of deformation

Strain/Temperature dependence

- Physics of the solid state 1

- Hyper-elasticity, viscoelasticity, damage of polymers

From the melt to the solid state: temperature and time dependence of the mechanical response

In the molten state:

- * laminar shear flow
- * shear stress
- * shear strain
- * shear rate
- * rheological equations
- * viscosities (dynamic, cinematic, relative, specific, intrinsic)
- * Newtonian fluids (linear)
- * Non-Newtonian fluids (shear softening or shear thinning, pseudoplastic, shear thickening)
- * Power law (Ostwald's equation)
- * 3-parameter models (Ellis, Williamson, Shragrow)
- * Generalized flow
- * Plastic liquids (Bingham, Casson, Hershel-Bulkley's equation)
- * Thixotropy
- * Influence of temperature, molar mass and pressure on the flow
- * Influence of time

In the solid state:

- * Temperature-dependence of quasi-static mechanical response
- * Linear viscoelasticity (Newtonian viscous fluid vs. Hooke's elastic solid)
- * Viscoelastic models (Kelvin-Voigt, Maxwell, generalized K.V and M.)
- * Relaxation and creep tests
- * Enthalpic and entropic elasticity
- * Quasi-static vs. dynamical mechanical responses
- * Distribution of the relaxation times
- * Time-temperature superposition

Diffusion and phase transformations

Diffusion in the solid state

1. Introduction

Experimental evidence

Importance in material science: phase transformations, soldering, oxidation...

Brownian motion

Atomic scale mechanisms of diffusion

2. The two Fick laws

The first Fick law

Einstein atomistic expression of diffusion coefficient

The influence of temperature

Interstitial diffusion

Substitutional diffusion and the vacancy mechanism

The second Fick law

Self-diffusion and vacancy diffusion

Application to homogenisation of solid solutions, the growth of a second phase, cementation...

3. Heterodiffusion

Kirkendall effect, the lattice motion
The mutual diffusion in concentrated alloys, Darken equation
Inverse Kirkendall effect

4. The short circuits of diffusion

Grain boundaries, dislocations

5. Diffusion under a driving force

Nernst-Einstein equation

Mobility and Darken equation

Thermodynamic equilibrium and diffusion: the Boltzmann distribution

Nature of transport forces: chemical, electric field, stress, temperature gradient...

A few applications: creep, oxidation, semiconductors...

- Diffusion in Polymers

The lecture deals about the general aspects of diffusion (gas and liquid) in polymers and covers a wide range of industrial problematics. This includes experimental approaches and setups regarding sorption and permeation measurements. The obtaining of sorption isotherms and their meanings in terms of polymer structure are developed as well as the procedures to calculate the diffusion coefficient with and without dependence with concentration. Plasticization and swelling are also studied. Finally some notions about osmotic pressure are given.

- Phase transformations 1

Chapter I: Solidification

I-In pure element

II-In binary alloys

III-Minor segregation phenomena

Chapter II: Diffusive transformations in solids

I-Nucleation and growth theory

1. Homogeneous nucleation

2. Heterogeneous nucleation

3. Growth

II-Spinodal decomposition

III-Coarsening

Chapter III: Eutectoid and discontinuous transformation

Chapter IV: Martensitic transformations

Foreign languages

- English in Master 1 degree

- English in Master 2 degree

Prerequisite: B1 level Common European

Framework:

Curriculum:

*Methodology: Learn how to write an abstract, describe and interpret a graphic, introduce a chemistry laboratory.

*Oral work: Practice job interviews, personal presentations, talking about your skills and career objectives in an effective way, understand course-

related presentations and communicate to others about it, learn how to present a scientific report, present annual project as a group.

* Written work: Design CV and cover letter, write professional e-mails, translation (scientific documents, course-related press articles...)

Practice for CLES and TOEIC tests.

*Expand vocabulary (write a glossary): Polymers, Nanotechnology, Nanoporous, Rusting, Probe, Coating, Brittle, Embrittlement, Malleable, Environmentally-friendly, Refraction, Cluster ...

- **Materials sciences and Mechanical Engineering**

Lectures and Conferences made by different invited speakers from Russia, Italy, United States, etc.

Business and employability

- **Knowledge of business, Management**

- **Technological survey, Intellectual property**

Industrial materials

- **Metals and metal alloys**

- **Polymers**

1. Introduction and history of polymers
2. Structural aspects of polymers: notion of monomer, polymer, macromolecule, copolymer, blend, configuration and conformation, tacticity, covalent bond, average molecular mass, polydispersity index, the main polymers
3. Categories of polymers: thermoplastics, thermosets, elastomers
Van der Waals interactions, H-bonds, covalent bonds, linear polymers in solution and in the solid state, polymerization of thermosets, industrial thermoset, entropic vs. enthalpic elasticity, mechanical properties, thermal properties, hyper elasticity, thermoplastic elastomeric materials, industrial classification of polymers
4. Amorphous polymers, the glass transition: glass vs. amorphous, ageing, molecular mobility, thermodynamic aspects of glasses, heat capacity, structural relaxation, parameters which affect the glass transition of a polymer, Fox equation, free volume
5. Semi-crystalline polymers: fringed micelles, chained folded lamellae, chain extended crystals, spherulites, degree of crystallinity model of disordered regions between lamellae, optical aspects, X-ray diffraction analysis, two- and three-phase models, rigid amorphous fraction
6. Oriented polymers: fibers, blowing, mechanical properties
7. Crystallization of polymers, free energy, equilibrium melting temperature, role of the interface on thermal stability, germination and growth, dependence of the thickness of the lamellae with the crystallization temperature, Gibbs Thomson equations, kinetics of crystallization (Ozawa, Avrami)
8. Melting of crystals: dependence of the melting temperature, Hoffman and Weeks method, annealing, polymorphism
9. Blends of polymers: thermodynamical aspects
10. From polymers to plastics: additives, formulation, example of ABS and PVC

Materials properties 2

- Properties of macromolecular materials

The goal of this lecture is exploring the thermal and mechanical properties of macromolecular materials (from simple systems to complex systems like composites, nanocomposites, blends...) through different experimental investigations like DMA (Dynamical Mechanical Analysis), DSC (Differential Scanning Calorimetry), MT-DSC (Modulated Temperature Differential Scanning Calorimetry). The role of interfaces (between matrices and fillers as an example) on thermal and mechanical properties will be highlighted.

More specifically, concerning the mechanical properties of composites materials, the outline will be the following:

- Elastic parameters of a composite ply in longitudinal and transverse fibers directions.
- Elastic parameters of a composite ply for random direction.
- Breaking behavior in composite unidirectional ply regarding fiber reinforcement.
- Stress transfer in composites with variable fiber length

- Relationship between microstructure and plasticity in metals

I – Elastic theory of dislocations

- Strain and stress fields
- Energy of dislocation line
- Peach- Koehler force

II- Dislocation mobility and plasticity

- Peierls – Nabarro stress
- Dislocation glide
- Relationship between dislocation glide and deformation speed
- Influence of temperature on dislocation mobility

III- Hardening mechanisms

- Interaction dislocations-dislocations – work hardening
- Interaction with grain boundaries – Hall Peatch
- Solid solution hardening
- Second phase hardening
- Expression of the yield stress

Physics of condensed matter

- Physics of the solid state 2

1. Introduction

- 1.1 General considerations: structural and functional materials
- 1.2 The main classes of materials

2. The theory of energy bands

- 2.1 Reminder and summary of Sommerfeld theory of free electrons and density of state $g(E)$
- 2.2 The formation of forbidden energy bands and Brillouin zones
- 2.3 Energy bands and conductivity, metals, insulators and semiconductors, the colour of metals, Peierls transitions, Anderson localisation, Mott transition

- 2.4 Bloch theorem and band structure
- 2.5 Reduced zones, the concept of effective mass and hole
- 2.6 Fermi surfaces
- 2.7 The tight binding method, Hartree-Fock approximation, introduction to the density functional theory (DFT)
- 3. Semiconductors
 - 3.1 Historical developments, applications in microelectronics (LED, diodes, transistors)
 - 3.2 Intrinsic semiconductors
 - 3.3 Extrinsic semiconductors
 - 3.4 PN junction, the diode and transistors: a quick introduction to applications in microelectronics

- Magnetic and dielectric properties

Numerical methods

- Monte Carlo Method

- I. Generalities on numerical simulations
 - Examples, usefulness of simulations, deterministic and stochastic methods, limitations
- II. Generalities on the Monte Carlo method
 - History, Ising model, basic principles (detailed balance condition), application fields of the Monte Carlo method
- III. Monte Carlo method in the canonical ensemble
 - Canonical ensemble (background), detailed balance condition in the canonical ensemble, Metropolis algorithm, calculation of the thermodynamic quantities
- IV. Application of the Monte Carlo method to phase transitions
 - Phase transitions (background), phase transitions of the Ising model, finite-size effects (second order phase transition)
- V. Kinetic Monte Carlo method
- VI. Molecular dynamic
 - Basic principles, calculation of the interatomic forces, numerical integration of the motion equations (Verlet algorithm), limitations

- Atomistic and mesoscopic modeling of phase transformations in solids

- I. Mean field approximation
- II. Static concentration wave theory
- III. Phase field modelling
- IV. Phase field crystal modelling
- V. Solvers for the differential equations

- Calculation of thermodynamic properties by the Calphad method

- I. Thermodynamic basis of the CALPHAD method (CALculation of Phase Diagrams)
- II. Exercises with computer using the Thermo-Calc software:
 - Plotting of Gibbs energy curves
 - Plotting of binary and ternary phase diagrams
 - Plotting of isopleth diagrams in higher order phase diagram
 - Other kinetic applications

- **Industrial numerical methods (DAO/CAO – Thermocalc)**

Polymers physics

- **Polymers, plastics and plastic manufacturing**

Review on the main industrial polymers

- **Fundamentals about amorphous materials and glasses**

- Introduction on glassy dynamics, the molecular mobility in amorphous material.
- Free volume approach from the middle of 20th century to recent years.
- Understanding Arrhenius diagram for amorphous material using VFT-like equations.
- Structural relaxation processes and physical ageing in glass forming liquids.
- Fictive temperature.

- **Polymer ageing and degradation**

The lecture deals first about the basic and fundamental notions relative to chemical aging and degradation in polymers, including the causes of degradation, the associated mechanisms and their respective kinetics.

A particular attention is dedicated to photo-degradation and thermo-oxidation for the main families of polymers.

A review of the techniques allowing investigating chemical aging is proposed as well as a description of the major impacts it has on the macroscopic properties.

Finally the mechanisms involved in the stabilization of polymers will be detailed.

The last part of the course bring fundamentals about the biodegradation mechanisms.

- **Biopolymers et biocomposites**

The production of bioplastics from renewable resources is regarded as a more sustainable activity when compared with plastic production from petroleum, because it relies less on fossil resources as a carbon source and also reduces bad emissions during the degradation steps. "Green" plastics attract increasing attention and give rise to an emerging industry that is focused on making convenient living consistent with environmental stability. The bioplastics industry proposes new solutions based on corn (PLA), bacteria (PHA), sugar beet, potatoes, wheat, etc. This short-course describes these new macromolecular materials (applications, physical properties, strength, weakness,...) to get ready for the very next future of materials science and technology.

- **Nanostructured polymers**

- I. Polymer nanocomposite materials: generalities, definitions
- II. Carbon nanotubes as nanofillers
- III. Layered silicates (clays) as nanofillers
- IV. Study example: MMT/Carbon nanotubes/Polymer blends

- **Semicrystalline polymers**

- 1) Semi-crystalline polymers, new cases: case of flow induced crystallization, Shish Kebab crystallization, strain induced crystallization, role of copolymerization and additives on crystallization
- 2) Experimental technics: X-Ray Diffraction, pole figures and texture in drawn polymers, advanced thermal analysis, complete investigation of thermodynamics and physical quantities of an unknown polymers
- 3) Influence of crystals on the amorphous phase: anisotropy, gradient of molecular mobility, rigid amorphous fraction vs. mesophase

Physical metallurgy

- Corrosion

Electrochemical Corrosion and Oxidation at High Temperature

- I) Introduction
- II) Electrochemical Corrosion
 - Thermodynamic aspects (definition of basic electrochemistry, electrode potential, potential-pH diagram, ...)
 - Kinetic aspects (polarization curves, corrosion rates, passivity, ...)
 - The various corrosion mechanisms
 - Protection against electrochemical corrosion (design, material selection, cathodic and anodic protection, protective coating, inhibitors, ...)
- III) Oxidation at high temperature
 - Thermodynamic aspects of gas/metal reaction (stability of oxides, Ellingham diagram, ...)
 - Oxidation mechanisms (pure metal oxidation, alloys oxidation, internal oxidation,...)
 - Oxidation kinetics (oxidation rates laws, mechanical stresses in oxide layers)
 - High temperature oxidation protection (material selection, protective coating, practical examples, ...)

- Mechanical degradation

- Phase transformations 2

1. Ordering transformations
 - 1.1. General considerations
 - 1.2. Bragg-Williams mean field theory
 - 1.3. Katchaturyan concentration waves formalism and symmetries
 - 1.4. Ehrenfest classification of transitions (1st et 2nd order)
 - 1.5. The theory of Landau, metastability and instability, the two Landau rules
 - 1.6. Kinetics pathways, nucleation of ordered domains and spinodal ordering
2. Segregation of impurities to lattice defects
 - 2.1. Segregation to dislocation lines, Cottrell atmospheres
 - 2.2. Segregation to planar defects
 - Suzuki affects (stacking faults)
 - Equilibrium intergranular segregation (Mc Lean theory...)
 - Non-equilibrium segregation (quench effects)
3. Precipitation, un-mixing and thin film reactions
 - 3.1. Introduction and reminders (thermodynamics, diffusion)
 - 3.2. TTT diagrams, Mehl-Avrami-Johnson law

- 3.3. Regression effects in classical nucleation (Zeldovich / Turnbull)
- 3.4. Non-classical nucleation (J. Cahn...)
- 3.5. Growth mechanisms of precipitates (spheres, needles, platelets...)
- 3.6. Thin film growth, Deal and Grove law
- 3.7. Spinodal decomposition : cohérent, incoherent
Kinetics (Cahn-Hilliard, LBM theories...)
- 3.8. Coarsening, morphological evolutions and bifurcations

- **Materials exposed to radiation**

- I- Primary damage
 - Interaction particle – matter
 - Displacement threshold energy
 - Frenkel pair
 - Displacement cascades
 - Notion of displacement per atom
- II- Point defects and point defect clusters
 - Equilibrium concentration
 - Diffusion
 - Long term evolution – extended defects
- III- Segregation and precipitation under irradiation
 - Radiation enhanced diffusion
 - Radiation enhanced precipitation
 - Radiation induced segregation and precipitation
- IV- Impact on properties
 - Mechanical properties: irradiation hardening and embrittlement
 - Dimensional changes: creep, swelling, growth

- **Symmetries in solids**

- Crystal structures, Bravais lattices
- Symmetry properties (proper, improper)
- Stereographic projections
- Crystallographic point groups
- Space groups
- Determining the Space group of a Material
- Curie's symmetry principle
- Application of Curie's principle
- Symmetry and anisotropy of physical properties

Physics of nanomaterials

- **Elaboration and analyze of nanomaterials**

- I. Top down methods: nanolithography and etching processes
- II. Bottom up methods: growth of self-organized nanostructures on pre-structured surface, growth of thin films (sol-gel, sputtering, UHV evaporation, molecular beam epitaxy (MBE), pulsed laser deposition (PLD)...)
 - III. Low energy deposition of aggregates, ion implantation methods, mechanical alloying
 - IV. Metallic nanowires, carbon nanotubes, fullerene and graphene
 - V. Force field microscopies (AFM, ..), magnetic (SQUID, MFM, MOKE) and electric properties (PFM,..), spectroscopic techniques (CEMS, ...)

- Magnetism

- I. Magnetic quantities: background
- II. Model of the localized electrons
 - Magnetism of the free atom or ion
 - Magnetism of atoms in solid state matter
 - Paramagnetism (zero anisotropy)
- III. Model of the delocalized electrons
 - Model of free electrons
 - Pauli paramagnetism
- IV. Exchange interactions
 - H₂ molecule
 - Heisenberg hamiltonian
 - Exchange interactions in insulators (super-exchange)
 - Exchange interactions in metals
- V. Magnetic order (localized magnetism)
 - Ferromagnetism (molecular field theory)
 - Antiferromagnetism (molecular field theory)
 - Ferrimagnetism (molecular field theory)
- VI. Magnetocrystalline anisotropy (single-ion anisotropy)
 - Phenomenological approach
 - Microscopic approach
- VII. Domains and hysteresis
 - Dipolar interactions (demagnetizing field)
 - Magnetic domains
 - Domain wall (Bloch, Néel)
 - Hysteresis loops

- Nanomagnetism

- Solid state physics and radiation-matter interaction

PART I

- I. Panorama of nano-objects: Nanowires, nanotubes, quantum wells, nanoparticles
- II. Elements of band theory (3D state density, effective masses, forbidden band, states in the forbidden band)
- III. Semiconductors with reduced dimensionality (1D, 2D, 3D confinement: computation of the densities of states $g(E)$, $E(k)$)

PART II

- I. Optical properties (absorption, emission) of metals, semiconductors, insulators
- II. Link to the band structure
- III. Plasmonics and introduction to nano-plasmonics
- IV. Introduction of excitons, luminescent and colored centers

- Nano-optics and Nanophotonics

- I. Materials for optics and nano-optics
- II. Quantum confinement effect in semiconductors
- III. Optical physics of quantum dots, quantum wires and quantum wells
- IV. Plasmonics (from bulk metal to localized surface plasmon resonance)
- V. Introduction of system for nanophotonics (photonic crystal, nano-bio-photonic, ...)

- Nanoelectronics

1. Introduction
 - From semiconductor physics to nano-transistors
 - Links with daily high technology devices
2. Reminder
 - Semiconductors, doping
3. PN junction and diode
 - Classical diodes and schottky diodes
 - Light emitting diodes (LED)
 - Quantum wells and Laser diodes
 - Photovoltaic cells
4. Bipolar transistor
 - NPN et PNP
 - Amplification
 - Planar technology
 - Integrated circuits
5. Field effect transistors
 - MIS structures, MOSFET, CMOS
6. Microélectronique
 - VLSI integrated circuits, Moore law
 - Random access memory(RAM, DRAM)
 - Read only memory (ROM, ...)
 - Flash memories (EPROM, USB)
 - CCD devices
7. Alternative nanoelectronics
 - Bottom-up approaches based on nano-objects (nanowires...)

Characterization techniques

This lecture allows the student to have knowledges on different techniques of characterization as:

- Transmission Electron Microscopy (MET)
- Scanning Electron Microscope (SEM)
- Fourier transform infrared spectroscopic analysis (FTIR)
- Tomographic Atom Probe (TAP)
- Mossbauer Spectroscopy
- Differential Scanning Calorimetry (DSC)
- Modulated Temperature DSC (MT-DSC)
- Modulated Dynamical Analysis (DMA)
- Broadband Dielectric Spectroscopy (BDS).

The student will have also to manage a scientific project related to an industrial contract, fundamental researches, etc. in parallel to the common schedule. It will be the occasion for him to test some of these characterization techniques.

Business and employability

- Employability
- Standards and quality

French, European and International standardization
France and Europa: Regulations, Directives and other acts
New approach: directives and standards, CE marking
Example of application: Equipment for potentially explosive atmospheres (ATEX Directive)
Quality: History and definition
Standard study: ISO 9001 – Quality management system

Internship /duration: 3 months in Master 1 or 6 months in Master2

Laboratory or company, France or abroad