S9-UE1 Nanophysics, Nanoelectronics 4 ECTS

S9-UE1-M1 Nanophysics 2 ECTS

Professor : Philippe Schieffer (UR, 15H lectures)

I- Electron transport in nanostructures
- Classical transport, characteristic lengths
- Ballistic transport, Landauer Buttiker approach
- Coulomb blockade; Single electron transistor
- Aharonov-Bohm interferences

II- Fundamental concepts in spin polarized (diffusive) transport
- Introduction: electrical conductivity in ferromagnetic materials
- Spin-polarized electrons/matter interactions
- Giant- and Tunneling- magnetoresistance effects
- Semi-classical theory of magnetoresistance
- Spin electronics in semiconducting nanostructures

III- Semiconductor nanostructures for optoelectronics
- Introduction about bulk semiconductor band-structures
- Band-structure in quantum wells
- Electronic levels in Quantum dots
- Quantum well lasers

S9-UE1-M2 Nanoelectronics 2 ECTS

Professors : Jean-Pierre Landesman (UR, 10H lectures), Pascal Turban (UR, 10H lectures)

I- General Introduction : ”Historical” introduction to the route leading to nanoelectronics

II- Future architectures for nanoelectronics elementary devices : multi-level logics, cellular automates, neuronal networks, quantum computing

III- Systems operating with a limited number of electrons – Single Electron Transistors, memory cells

IV- Possible applications of nanotubes and nanowires to the microelectronics industry

V- Semiconductor nanowires, fundamentals and applications

VI- Spin electronics devices (GMR and TMR based sensors, spin-transistors)

VII- Molecular electronics : from fundamentals to applications

Conclusion

S9-UE2 Micro and Nanotechnologies, Thin Films Technologies 5 ECTS

S9-UE2-M1 Micro and Nanotechnologies 3 ECTS, 12H lectures+16h lab

Professors : Laurent Pichon, Jean-Pierre Landesman, Hervé Lhermite (UR)

Lectures (12h): Issues of nanotechnologies and Moore's law, IRDS Roadmaps, technologies for nano-objects synthesis (nanowires, nanotubes, nanoparticles), metals insulator semiconductor thin films deposition techniques (CVD, PVD, MBE), lithography (UV, electronic, AFM nanolithography, nano-imprint), doping techniques, dry and wet etching, micro- and nanodevices fabrication.

Hands on clean room practicals (16h) : complete realization of a devices based on silicon nanowires in a clean room facility, preparation/ characterization and nano-manipulation of nano-objects under electron microscopy, electrical characterization of silicon nanowires.

S9-UE2-M2 Module Thin film technologies 2 ECTS, 12h lectures+6h lab

Professors : Maryline Guilloux-Viry, Valérie Demange (UR)

The guideline of this lecture: how to control multi-element materials in thin films, mainly ternary or quaternary functional oxides for integration in devices?

Which deposition method to be selected for a given material? Which characterization methods to choose in a multiscale approach with respect to the composition, microstructure, morphology and structural properties to be investigated?

Introduction

Nucleation – Growth: thin films nucleation/growth modes, structure and morphology (amorphous, polycrystalline, textured, epitaxial), strain and stress, examples of structure/properties relationships. Illustrations with different functional materials.

Deposition techniques:

CSD, CVD, ALD, MBE, PVD, PLD : principles, advantages, limitations, according to multi-element functional materials in different chemical systems (oxides, sulfides, metals).

The strategy of the use of seed layers for the control of growth at nanoscale will be introduced.

Characterization techniques:

Chemical analysis: EDX – XPS – RBS – SIMS

Crystallinity: phase determination, epitaxy and heterostructures analysis by XRD, RBS and XPD. Complementarity and specifities of the methods and different configurations. Comparison with other techniques.

Morphology: SEM, AFM, X-ray reflectometry, thickness determination (ellipsometry, profilometry)

Specific real cases will be presented in a multiscale approach and according to integration in devices.

Lab : growth and complete analysis of a thin film by PLD, XRD, SEM, TEM

S9-UE3 Nanocharacterization 3 ECTS

S9-UE3-M1 Nanocharacterization 1.5 ECTS, 15h lectures

I- Nano-characterization by photons and neutrons

- Introduction: light-matter, neutron-matter interaction
- Elastic Scattering by nano-objects: Small angle scatterings, wide angle scatterings, diffractions
- Dynamic light scattering
- Examples of applications

II- Inelastic scattering and resonant processes

- Inelastic scattering and absorption-emission processes: polarizabilty-electric susceptibility
- Vibrational and Electronic transitions
- Raman scattering et inelastic neutron scattering: phonon, Nano-scale and phonon
- Spatial resolution: Optical Microscopy in far field and in near-field: Near field Scanning Optical Microscopy, Tip Enhanced Raman Spectroscopy, Super-spatially-resolved optical methods

III- Transmission Electron Microscopy (TEM)

- Introduction
- Electron/Matter interaction
- Constitutive elements of the microscope
- Imaging and diffraction in the TEM
- Analytical microscopy: EELS, EFTEM, EDXS

IV- Scanning Tunneling Microscopy (STM)

- Introduction: from tunneling to the microscope
- Experimental setup
- Applications
- Derived methods: BEEM, SP-STM

V- Atomic Force Microscopy (AFM)

- Cantilever/surface interactions
- Contact, non-contact, tapping mode
- Applications and derived techniques (force spectroscopy, MFM, EFM, nanolithography…)

S9-UE3-M2 Experimental techniques in research lab, 20h lab

In lab practical: complete study of a nanomaterial/nanostructures by a multitechnique approach combining TEM, EELS, EDX, STM, AFM, Raman imaging and spectroscopy.

S9-UE4 Innovation, Valorisation, ZOLILAPLOT 2 ECTS

S9-UE4-M1 Innovation, Valorisation, 1ECTS

Professor : Jaques Prono 10H lectures, Cabinet Distingo Conseil

Introduction to innovation management, intellectual property, technology transfer.

S9-UE4-M2 ZOLILAPLOT (beginner or advanced), 1ECTS

Professors : Franck Thibault, Mariko Dunseath-Terao, Flora Blanco (24h online, UR)

Introduction to Zotero (bibliography tool), Linux, Latex and various plot tools.

S9-UE5 Scientific English 3 ECTS

15H CM, 15H TD

Professors : Sean Mac Namara, Ian Sims (UR), 15h lectures, 15h tutorials

Training to scientific communication in English (oral and written).

S9-UE6 Quantum Simulations 3 ECTS

Professors : Sylvain Tricot (UR), Oleg Ruben (MacMaster University), 6H lectures, 20H lab

This UE aims to give a practical training on some quantum numerical methods (and associated computational tools) pertinent for the modelling of physical properties of (nano-)materials. The investigated systems should be relevant in one or several domains of application addressed in the modules of the Master Nano program.
The student will be able:
• to develop a modelling approach for the description of a physical system and its properties
• to identify by modelling the pertinent physical parameter(s) responsible for the observed properties
• to develop a rigorous numerical experiment strategy towards an optimized description of the studied physical problem
• to identify and explain the eventual limitation(s) of the developed simulations
• to compare the simulation results with available experimental data from literature or other published numerical results
• to produce a synthetic scientific report summarizing the developed modelling strategy, main results and associated interpretations

:

1. Introduction to Density Functional Theory (DFT)
2. Tutorial on GPAW code
3. Introduction to Multiple Scattering (MS) theory for electron spectroscopies
4. Tutorial on MSPEC code
5. In lab practical on DFT or MS simulations : scientific cases

S9-UE7 Nanomaterials, Nano-bio-objects 4 ECTS

S9-UE7-M1 Nanomaterials, 2ECTS

Professors : Valérie Marchi (9H lectures, UR), Jean-Christophe Le Breton (6H lectures, UR)

Introduction

I- General considerations related to the nanoscale

II- Main strategies of synthesis of nanoparticles (vapor phase, liquid phase)

III- Self-organisation, self-assembly and manipulation of nanoparticules ; colloids

IV- Metallic nanoparticules
- some methods of synthesis
- electrical, optical and plasmonic properties; catalytic effects; interest for applications.

V- Magnetic nanoparticles
- ferromagnetic metal nanoparticles
- metal oxide nanoparticles

VI- Semiconducting and dielectric nanoparticules

VII- Carbon nanostructures
- structure and electronic structure of carbon allotropes
- fullerenes and derivatives
- carbon nanotubes
- graphene and single layer materials (h-BN, TMDCs, MoS_2…)

S9-UE7-M2 Nano-bio-objects, 2ECTS

Professors : Véronique Vié (10H lectures, UR), Bernard Cathala (10H lectures, INRA)

Introduction

I- Biomolecules and their organization
- Introduction
- Bacteria, mammals and plants cells
- Biomolecules : structure, conformation and functions
  - Nucleotides, ADN and ARN
  - Amino acids, peptides and proteins
  - Lipids
  - Oligo- and polysaccharides
- Biochemistry principles
  - Molecular recognition (specific interactions, diffusion and thermal motion)
  - Water and its effect on molecules in solutions

II- From unique molecule to supramolecular assemblies
- Manipulation methods at the single molecule scale
- Supramolecular assemblies and bio-mimetic models

III- Nanobiomaterials

- Natural nanomaterials, nanocomposites examples : Structure and properties of remarkable natural nanocomposites (bones, wood, silk).
- Organic/inorganic hybrid nanomaterials
  -Bio-sourced nanocomposites
  -dispersed systems : emulsions, gels, foams
  -Thin films
  -Biosensors
  -Hybrid biomolecules/inorganic nanomaterials (Biomolecules/CNT, protein/SiO_2,…)

S9-UE8 Surface Functionalization, Molecular Simulations 3 ECTS

S9-UE8-M1 Surface Functionalization, 1.5 ECTS

Professor : Bruno Fabre (10H lectures, UR)

I- Adsorption on surfaces

II- Surface functionalization

Motivations

Immobilization procedures

Characteristics and properties

Applications

III- Deposition techniques

Vapor deposition

Soft matter deposition

- Self-assembled monolayers
- Covalently bound monolayers

IV- Molecular patterning of surfaces

V- Surface characterization techniques

S9-UE8-M2 Molecular Simulation, 1.5 ECTS

Professor : Maxime Vasssaux (UR)

This lecture presents the theoretical and numerical background to well apprehend molecular and mesoscopic simulations to predict and reproduce macroscopic properties and to rationalize them from a microscopic standpoint.

- Fundamental concepts of molecular and mesoscopic simulation: molecular dynamics and Monte-Carlo method
- Statistical physics, micro-macro transition, multi-scale simulations, calculation of macroscopic properties: free energy, surface tension, diffusion coefficient, viscocity, adsorption properties
- Exploring microscopic processes: radial distribution, average force potential, density profile, etc.
- Direct application to nanotechnology: confinement of fluids in nanopores; phase transitions, greenhouse gas capture and removal

S9-UE9 Nanosciences and nanosystems in photonics, Nanomagnetism, 3 ECTS

S9-UE9-M1 Nanosciences and nanosystems in photonics, 1.5 ECTS

Professor : Bruno Bêche (UR, 12H lectures)

Integrated photonics and nano-photonics devices by hybrid and coupled thin layer process. The goal of such micro- and nano-photonics module is to present integrated photonics and materials with a view to highlight the recent development of specific hybrid processes (such as biomolecular film deposition, assembled growth and handling of optical elements, plasma treatments coupled with microtechnologic thin layers processes, and microfluidic devices) for the realisation of optical components devoted respectively to sensors (physical, chemical, biologic measurements) and to optical telecommunications applications.

Program:

1. Introduction to integrated photonics, overview

2. Theory of advanced electromagnetic waveguides

3. Micro-photonics components and hybrid process for sensors and optical telecommunication applications

4. Nanophotonic / sub-wavelength photonics by coupling hybrid thin layer process: Examples of photonic structures based on photonic crystals (filters, detectors, VCSEL).

S9-UE9-M2 Nanomagnetism, 1.5 ECTS

Professor : David Dekadjevi (UBO, 8h lectures)

Understand and predict the magnetic properties of low-dimensional systems (nanoparticles, nanowires, thin films, patterned elements). Engineer magnetic materials for specific applications.

Program:

1. Introduction to magnetism: Zeeman, anisotropy, exchange and magnetostatic energies; Magnetic domains and domain walls, Stoner and Wohlfahrt model.

2. Magnetism and magnetic domains in low dimension systems: surface and interface anisotropies, magneto-elastic anisotropy, domains and domain walls in thin films and nanostructures, vortices and skyrmions.

3. Magnetization reversal in low-dimensional systems: coherent rotation, nucleation and propagation, hysteresis loops, precessional dynamics of magnetization.

4. Elements of magnetometry