NP 428 Functional materials 9 ECTS

Organisation :

Effective duration: 12 weeks
Lectures : 53 hours
Practicals (5): 22 h
Projects : 10 h
Total : 85 h

Examination :

Written examination, project report

Teachers :

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Plan of lectures (53 hrs)

CHAPTER I . MAGNETISM: MATERIALS AND APPLICATIONS (16 h).

1. Principles.
    a. Magnetostatics.
    b.Classical and quantum phenomenology.
    c.Magnetic anisotropy.
    d.Magnetic domain walls and domains.
    e.Magnetization process.
2. Permanent magnets.
    a.Electro-mechanical, Magneto-mechanical devices and permanent magnetic field sources.
    b.Permanent magnets for very small devices. Application to electric motors.
    c.Permanent magnetic flux sources.
    d. Materials for permanent magnets.
    e. - AlNiCo and FeCrCo : spinoidal decomposition.
    - Hexagonal ferrites and other oxide magnets.
    - Rare earth-transition metal intermetallics.
3. Electronic transport in magnetic materials.
    a. Electrical resistivity.
    b. Giant magnetoresistance.
    c. Spin tunneling.
4. Magnetic recording
    a. Overview.
    b. Particulate recording media.
    c. Thin film recording media.

d. Recording heads.

CHAPTER II. OPTICAL PROPERTIES OF NANOMATERIALS (14 h)

1. Fundamentals
    a. Quantum mechanics of electrons and photons
    b. Absorption and spontaneous emission
2. Optical properties of semiconductors
    a. Band structure, effective masses, density of states
    b. Absorption
    c. Radiative recombination and lifetime
d. Concepts of semiconductor devices
    3. Semiconductor nanostructures
    a. Growth and characterization
    b. Electronic confinement
    c. Heterostructures: quantum wells, wires and dots
    d. Optical transitions in nanostructures
4. Applications
    a. Light emitting diode
    b. Quantum well laser

CHAPTER III. FUNCTIONAL SURFACES (23h)

1. Single-crystal clean and adsorbate-covered surfaces
    a. Principles: surface electronic and geometric structure and related UHV characterization spectroscopies (UPS, XPS, NEXAFS, LEED, TPD, HREELS)
    b. Surface science and catalysis-UHV versus “real” conditions-pressure gap temperature gap
    c. Model adsorption systems with various UHV-compatible techniques
    d. Ammonia synthesis: an example of close correlation between surface science and catalysis
    e. Surface reconstruction for semiconductor single-crystal substrates: Si(100), Si(111)
    f. Reactivity of semiconductor surfaces towards various organic molecules
    g. Chirality on surfaces: generalities and examples

2. Surfaces in soft matter
    a. The molecular control at air/solid and liquid/solid interfaces: organized organic monolayers
    b. From organized organic monolayers to ordered liquid crystal thin films
    c. The study of soft interfaces in soft matter: scanning probe microscopies.

Laborations (22hrs)

(1) Growth of magnetic thin films on semiconductor by Molecular Beam Epitaxy. (4 hrs)
(2) Characterization of the magnetic properties by magneto-optical Kerr effect. (4hrs)
(3) Low temperature photoluminescence of semiconductor nanostructures (6 hrs)
(4) Characterization of a LED based on semiconductor nanostructures (4 hrs)
(5) Characterization of the molecular network of 8CB molecules on top of MoS2 substrate by Scanning Tunneling Microscopy. (4hrs)

Project (10 hrs)

The aim of a project is to give the student the opportunity to study in detail a topic by directed reading and independent study including a critical review of literature.

Research using academic journals, textbooks and computer-based resources;

Topics: Electron Paramagnetic Resonance, Nuclear Magnetic Resonance, Insertion devices for synchrotrons, Spin valves and spin switches, High density Magnetic RAM (MRAM), Semiconductor nanocristals as single photon light sources, Quantum cascade lasers, Two-level systems for quantum information processes, Optical techniques for the observation of isolated nanostructures, Polarization effects and spin manipulation, Atomic Force Microscopy in water : the study of biological materials