

Subject: **Nanomaterials: Synthesis and processing**
Semester: **Spring**
ECTS Credits: **5**
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Dep. Physics, F-UdG
Dep. Molecular Nanoscience and Organic Materials, ICMAB-CSIC

Objectives:

General objectives and skills that the student should obtain at the end of the course.

General Objectives of the course:

- To give a general vision of the different procedures for preparation of nanometric materials: bottom up and top down.
- To consolidate knowledge of multiple techniques to obtain nanomaterials following the bottom up approach.
- To know the importance of the synthesis method in the material properties.
- To give a general vision of applications of nanomaterials in diverse fields.
- To give practical experience of nanomaterials synthesis and characterization through training sessions.
- To show some significant bibliographical references in this area.

Competences:

- To understand and differentiate synthetic strategies in nanomaterial preparation and treatments.
- To know the fundamental concepts for designing a synthesis procedure.
- To attain skills in managing the bibliographical sources.

CONTENTS: Subjects

Introduction. Fundamental concepts : (2 sessions: *E.Bertran*)

Materials science and technology at the nanoscale. Materials, nanostructure and properties. Pavlov law. Nanostructured systems. Thin layers and multilayers. Surfaces, nanostructured interfaces. Cluster formation. Classic theory of clusters nucleation.

Nanomaterial concept:(2 sessions: *L.Mestres*)

Nanomaterials: concept and typology. Methodological approaches to nanomaterials: synthesis (bottom-up) and fabrication (top-down). Classification of synthetic methods. Importance of supramolecular chemistry and phase separation as synthesis tools.

Synthesis and Processing of nanomaterials:

(2 sessions: *L.Mestres*; 2 sessions: *M.Ll.Perez*; 4 sessions: *D.Amabilino*; 2 sessions: *S.Dosta*)

Nanostructures of zero dimensions:

Particle synthesis by chemical methods. Homogeneous Nucleation: Growth factors. Heterogeneous nucleation: Thermal oxidation, kinetic controlled synthesis: micelles, spray pyrolysis, Template-directed methods. Covalent synthesis: iterative and self-assembly. Complementary methods: Sonochemistry, microwaves, Compressed fluids.

Nanostructures of one dimension:

Nanowires, nanorods and nanotubes. Crystalline growth. Template-directed synthesis: electrochemical and electrophoretic deposition. Covalent synthesis and self-assembly.

Nanostructures of two dimensions:

Thin Films; Chemical Vapour Deposition (CVD), Atomic Layer Deposition (ALD), Layer by layer deposition. Langmuir-Blodgett Films. Electrochemical deposition. Sol-gel Films. Synthesis based in templates. Self-assembled monolayers. Nanostructures produced by physical methods. Super-saturation. Nucleation. Coalescence. Transport and collection of particles. Crystal Structures. Thin films: Physical vapour deposition (PVD): Thermal and e-beam evaporation, sputtering, ion-beam deposition, surface treatments.

Nanostructures of three dimensions:

Application of the synthesis and organization methods for obtaining nanomaterials. Polymers, Zeolites, Nano-Micro and Mesoporous. Nanocompounds, nanocrystalline materials, soft matter. Organized membranes. Ceramics and nanocompounds processing: polymer/ceramic systems, polymer/metal, ceramic/ceramic, ceramic/metal. Multilayers. Processing and deposition of thin films. Mechanical processing.

Thermal treatments: (1 session: *P.Roura*)

Thermodynamics of gas-solid reactions. Ellingham diagrams. Kinetics. Synthesis of nanowires and nanotubes. Examples of carbon nanostructures. Preparation of multilayers and nanostructured complex oxides from molecular precursors. Heat treatments: decomposition, crystallization and epitaxial growth.

Properties and Applications: (2 sessions: *S.Dosta*; 3 session: *P.Roura/J.Farjas/J.J.Suñol*)

Nanomaterials properties:

Structure and characterization of nanostructured materials. Mechanical properties. Plastic deformation and nanostructured materials fracture. Hardness, tribology, friction and wear, at the nanometric scale. Phase transformations induced by tension in nanostructured materials. Properties of one dimension nanostructures: nanowires, nanorods and nanotubes. Superconductive properties. Magnetic properties. Magnetic Supernetworks. Giant magnetoresistance.

Energy applications:

Nanotechnology applied to improve photovoltaic conversion process. Solar cell quantum dots based. Nanostructured thin films: energetic use. Superconductive tapes for energy generation and transport.

Magnetic applications:

Materials and magnetic devices. Organized magnetic nanostructures.

Sensor applications:

Nanostructured sensors. Catalysts with nanostructured surfaces. Integration of nanostructures in advanced devices. Nanotechnology in the electronics industry. Sensors, MEMS, NEMS.

Biomedical applications:

Encapsulation and drug delivery. Biocompatible nanomaterials.

Practices: Laboratory Sessions (4 sessions: *E.Bertran* + *M.Ll.Perez*)

There will be four lab sessions from 2:00 hours each, and carry out experiments chosen from the following list:

1. Production and recollection of silicon nanometric particles by means of CVD plasma activated.
2. Production of SiO₂ nanometric particles by sol-gel. Counting and distribution of nanoparticles using laser dispersion.
3. Observation y characterization by SEM. Counting and distribution of nanoparticles using image treatment techniques.
4. Deposition of optic thin films (MgF, SiO₂, Ta₂O₅) by means of thermal evaporation in vacuum. Measurement of optical transmittance.
5. Deposition of metallic thin films by means of DC magnetron sputtering. Measurement of the width and electric conductance.
6. Observation and characterization of structural properties of multilayer systems by TEM.
7. Measurement of the electric characteristics in a nanostructured oxide sensor of In and Sn.
8. Magnetic nanoparticles. Magnetic separation of nanoparticles in solution. Ferrofluids.
9. Analysis of a multilayer system with X-ray diffraction. Characterization of the bilayer period.
10. Characterization of luminescence in systems of nanoparticles in suspension.
11. Polymeric (PMMA) layer deposition by spin-coating with embedded silicon nanoparticles.
12. Structural characteristics by SEM of different kind of nanoparticles (nanoparticles produced by means of plasma, sol-gel, spin-coating).
13. Solution synthesis of gold nanoparticles.
14. Gold nanoparticles layering on glass

Time distribution plan:

Classroom attendance: 44 hours (20 lectures in classroom + 2 exam sessions)

Laboratory attendance: 8 hours (4 laboratory sessions)

Tutored study: 16 hours

Self study: 78 hours

Bibliography

Books:

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Journals and papers:

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- XIA, Y. et al. One-dimensional nanostructures: Synthesis, Characterization and Applications, ADVANCED MATERIALS 15 (5): 353-389 2003.