UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Chemistry of Inorganic Materials

2324-1-FSM01Q005

Aims

Describe and discuss advanced methods for the synthesis of functional inorganic and hybrid organic-inorganic materials. Focus is on the choice of precursors and process conditions for synthesizing materials with the required composition, structure and physico-chemical properties. Owing to the dominance of crystalline materials students will learn fundamentals of crystal nucleation and crystal growth mechanisms from the melt, solution (low and high temperature) and vapor. Advanced aspects of inorganic chemistry, including acid/base reactions, oxidation/reduction reactions and stability in water and other solvents, will also be discussed giving further skills for a sound selection of materials and synthesis parameters for given applications.

Students will acquire basic knowledge about relevant advanced inorganic materials and synthetic methods with process parameters. This will enable the student to select approach, method and parameters best suited to fully control and optimize the synthesis of inorganic functional materials. This course logically follows and completes the mandatory course Strategies for materials synthesis – Inorganic strategies for materials synthesis also held in the first semester.

Contents

Advanced synthesis of functional materials (single crystals, polycrystalline powders, films, and ordered porous materials): synthesis of solids from the gas phase, from melts and solutions at low and high temperature, low and high pressure, exploitation of sol-gel processes. Fundamentals of classical and non-classical nucleation theories of crystals and growth mechanisms at the crystal surfaces. Influence of additives on crystal growth. Advanced definitions of acids and bases, acid/base properties of inorganic material, redox properties of inorganic materials, phase diagrams and stability in water and other solvents.

Detailed program

Nucleation of crystals and crystal growth mechanisms: classical and emerging non classical point of views on nucleation phenomena. Structure of crystal surfaces and their relation to growth mechanisms. Dependence of crystal morphology on growth parameters. Planning of crystal growth experiments. Kinetics versus thermodynamics. Effects of foreign substances: impurities and additives.

Synthesis of solids from the gas phase: Chemical and Physical Vapor Deposition (with sister techniques such as sputtering, thermal evaporation, vapor phase epitaxy, Chemical Vapor Infiltration, ..) with kinetic models, reactor types, features od reactants

Synthesis of solids from melts and solutions: crystal growth from the melt: general features and special techniques (Verneuil, Bridgman-Stockbarger, Czochralski, Kyroupolos, Skull method, Floating zone). Growth from low and high temperature solutions (solvothermal and hydrothermal processes, flux growth). Precipitation reactions and control of crystal morphology. The role of additives/impurities.

Synthesis of microporous materials: ordered porosity by “templating agents”; synthesis of zeolites and metal-organic frameworks. Solvothermal methods versus low temperature solution methods. Zeolites and MOF databases.

Synthesis of hybrid organic-inorganic perovskites (HOIPs): strategies and planning - from ReO3 crystal structure to +3000 hybrid perovskites (3D phases and 2D Ruddlesden-Popper and Dion-Jacobson phases) for photovoltaics, lasers, detectors, catalysts, etc. Miths and fake news in HOIPs: a critical evaluation of scientific literature. The Perovskite database.

Synthesis of bioinspired materials: biomineralization processes and the role of crystal nucleation and growth additives. Biogenic materials and new biomimetic smart materials.

Synthesis of inorganic pigments: general properties of pigment particles (particle size, size distribution, surface area and chemistry). General synthetic methods for pigment particles. Functional pigments.

Reactivity and stability of inorganic materials: Advanced definitions of acids and bases, acid/base properties of inorganic material, redox properties of inorganic materials, phase diagrams and stability in water and other solvents, including molten salts.

Environmental issues and inorganic materials.

Prerequisites

Chemistry of inorganic materials is based on an interdisciplinary approach exploiting general and inorganic chemistry, organic chemistry, physical chemistry (thermodynamics and chemical equilibria) and basic knowledge of crystallography.

Teaching form

Lectures will be given in English with support by video projection of text, schemes, diagrams, pictures and movies.

Textbook and teaching resource

Reference general textbook:
Synthesis of inorganic materials - U. Schubert, N. Hüsing - (2019) - ebook

Reference textbooks:

- The inorganic chemistry of materials: how to make things out of elements - P.J. van der Put - (1998)
- Solid state chemistry. Compounds - Eds. A.K. Cheetham, P. Day - (1992)
- Springer handbook of crystal growth - G. Dhanaraj, K. Byrappa, V. Prasad, M. Dudley Eds. - (2010) - ebook
- Inorganic Pigments - G. Pfaff - (2017) - ebook
- Modern inorganic chemistry synthesis – R. Xu, W. Pang, Q. Huo Eds. - (2017) – ebook
- Inorganic chemistry – D. F. Shriver, P. W. Atkins, C. H. Langford – Oxford University Press (1990)
- Inorganic chemistry – J. E. Huheey – Harper & Row Eds. (1983)

Specific review articles will be suggested for selected topics. Copies of the textbooks are available for lending from the university library.

Lecture handouts will be provided as pdf files uploaded on the e-learning platform.

Semester

1?? semester, starting on September 2023

Assessment method

The examination is performed through an oral exam without midterm tests. The teacher assesses if and to what extent the student has reached the course objectives, through a formal knowledge-based evaluation of the general topics delivered together with selected case studies. Parameters analyzed for producing the final score are capability and fluency during the interview to illustrate in a clear and sound way the topics delivered. A positive final graduation ranges from 18/30 to 30/30 cum laude based on quality and completeness level of the answers provided by the student.

Office hours

The teachers are available for help and discussion by arranging a meeting by email to: massimo.moret@unimib.it or livia.giordano@unimib.it.

Sustainable Development Goals

AFFORDABLE AND CLEAN ENERGY | RESPONSIBLE CONSUMPTION AND PRODUCTION | CLIMATE ACTION