UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Minerals at The Nanoscale

2324-1-F7401Q103

Aims

The course aims to describe mineral reactions, phase transitions, mineral growth and recrystallization features observable and understandable only if we focus our investigation at the nanoscale. These nanostructural and nanotextural aspects are fundamental to the understanding of many geological processes, of potential mineral applications and implications in environmental and health related issues. The matter is therefore of interest for mineralogists, petrologists, structural geologists, paleontologists and material scientists. The most striking aspects of this submicroscopic universe, as well as the instrumental techniques to gain access to it will be illustrated.

Contents

The course is organized in initial lectures that will introduce students to some basic concepts required to understand the main body of the course, such as an introduction to the reciprocal lattice, to diffraction and structural crystallography. The course will continue with lectures on the instrumental techniques suitable for investigations at the nanoscale, such as scanning and transmission electron microscopy, electron crystallography and microprobe analysis, scanning probe microscopy. The use of synchrotron radiation as well as free electron lasers applied to the research in geoscience and material science will be also discussed. The central part of the course is devoted to exemplify phenomena that occur at the nanoscale, such as phase exolutions, recrystallization features, cation ordering and disordering, phase intergrowths, polytypism and polysomatism. During the final part of the course student will attend practical session at the scanning and transmission electron microscopes and will be trained with the most common software for data analysis and representation.

Detailed program

Lectures (4 CFU, 28 hours)

o Crystal structures
o Reciprocal lattice
o Electron-matter interaction
o Electron diffraction
o The scanning electron microscope (SEM)
o Secondary electron images (SE) and backscattered images (BSE)
o Backscattered electron diffraction (EBSD)
o The transmission electron microscope (TEM)
o Bright field images (BF) and dark field images (DF)
o High resolution transmission electron microscopy images (HRTEM)
o Selected area electron diffraction (SAED)
o Energy dispersive system microprobe analysis (EDS)
o Wave dispersive system microprobe analysis (WDS)
o Cation ordering processes in columbites (implications for minerogenesis)
o Exsolution phenomena in ilmenite-pyrophanite minerals (implications on residual magnetism)
o Polysomatism:
- Pyroxenoids (implications for crystal growth history)
- Antigorite (implications for water transport in subduction zones and seismicity), Chrysotile (implications on surface reactivity)
- (Ca, REE)-fluorcarbonates (implications for mineral ore formation)
o Polytypism (kinetics and thermodynamic factors):
- Biotite
- Tobelite
- Moissanite
o Microstructure, nano-inclusions in brochiopodes (paleo-environnemental implications)
o Particulate airborne matter on honey-bee winds (health risk implications)

o Nanoprobe-surface interaction for the achievement of atomic resolution
o Scanning probe microscopies (STM, AFM)
o Chemical-physical-morphological surface analyses
o Elements of Synchrotron Studies
- History of synchrotron radiation, betatrons & cyclotrons
- Synchrotrons and FELs
- Main synchrotron and FEL techniques applicable to the geoscience and material science: XRD, XAS (XANES, EXAFS), XES, XRS, Synchrotron Mössbauer
- Research examples: i) studies of geo-materials at extreme conditions, ii) inclusions in diamonds studied in-situ using synchrotron radiation

Practical sessions (1 CFU, 12 hours)
o Training on PC programs for data processing and visualization, as Esprit, DigitalMicrograph, CrystalMaker, ProcessDiffract, Single Crystal, JEMS, WSXM, Gwyddion, etc.…
Lab sessions (1 CFU, 12 hours)
o F-SEM Zeiss Gemini 500 instrument presentation
o SEM-EDS, SEM-WDS, EBSD experiments
o Jeol TEM instrument presentation
o BF, DF, SAED experiments

Prerequisites

There are not prerequisites, although is recommended to attend interrelated courses, such as Deformation and metamorphism along convergent margins, Earth resources: Industrial minerals and rocks, Industrial and environmental mineralogy.

Teaching form

The course presents classroom lectures (4 CFU, 28 hours) on the most theoretical aspects of the subject and during which some case studies will be also illustrated. PC room session (1 CFU, 12 hours) during which students will be trained with the most common programs for data processing and visualization. Laboratory sessions (1 CFU, 12 hours) during which student will attend interactively SEM and TEM instrumental analyses.

Textbook and teaching resource

Lectures notes derived from the personal experience of the teacher will be made available. Recommended additional readings:
Andrew Putnis “Introduction to Mineral Sciences”. Cambridge University Press.
Mineral and reactions at the atomic scale: Transmission electron microscopy. Reviews in Mineralogy, 27, Mineralogical Society of America.
Nanoscopic approaches in Earth and Planetary Sciences. EMU Notes in Mineralogy 8. European Mineralogical Union.
Minerals at the nanoscale. EMU notes in Mineralogy 14. European Mineralogical Union.
Victor L. Mironov "Fundamentals of scanning probe microscopy" (http://ipmras.ru/~Mironov/SPM_textbook.html)

Semester

Second semester, first year, usually from the beginning of March to the end of May with a week of break (or more) during Easter holidays.

Assessment method

Development of an original project starting from a personal subject, even a hypothetical one, which includes the techniques discussed in class. Oral examination on the project and on the topics covered in class.

Office hours

All working days, by appointment, consistently with the off-site teacher's commitments, institutional commitments, and with the exception of summer, Christmas and Easter holidays.

Sustainable Development Goals