COURSE CODE Y1205: MINERALOGY-CRYSTALLOGRAPHY

Coordinator / Instructors

Prof. A. Godelitsas (agodel@geol.uoa.gr) / Prof. P. Voudouris, Dr. I. Megremi

Level: Undergraduate / 1st Semester

Type of course: General background (obligatory)

Lectures-seminars & laboratory work and exercises, optional fieldwork
Lectures 3 hrs/week, laboratory work and exercises 2 hrs/week (7 credits)

Admission requirements

Knowledge of Physics & Chemistry (parallel Courses Y1202 & Y1203)

Language: Greek and English (for Erasmus and international students)

OBJECTIVES

Minerals are the primary constituents of Earth materials and essential components of the Solar System and the Universe. They are also produced by living organisms to form a variety of biominerals. The fundamental understanding of their structure and composition is crucial for all fields within the Earth & Environmental Sciences. This course aims to provide knowledge on modern Mineralogy-Crystallography needed principally in Geology, and particularly in Petrology/Geochemistry/Ore & Economic Geology. Moreover, to introduce the students to macroscopic, microscopic, analytical, thermal, and X-ray techniques applied in minerals research.

LEARNING OUTCOMES

On completion of the course the student should have the following learning outcomes defined in terms of knowledge, skills and general competence:

Knowledge

The student understands the importance of minerals to society and to the study of the Earth & Environment; can explain how the properties of chemical elements and their bonds regulate the structure and composition of minerals; demonstrate how the crystal structure of minerals affects the external morphology and physical properties of a mineral (e.g. crystal symmetry, crystal habit); elucidate the concepts of symmetry, crystallographic axis, unit cell, enantiomorphism/chirality, Quasicrystals, allotropy, polymorphism, solid solutions/isomorphism, exsolution, polytypism, defects/impurities, epitaxy, topotaxy, intergrowths, twinning, mineral growth, refractive index, isotropic/anisotropic, pleochroism, optical axis, uniaxial/biaxial, birefringence/interference color; evaluate which basic methodology and techniques are appropriate for solving a mineralogical problem in different

scales -including micro- and nano-scale- (e.g. macroscopic examination, optical microscopy, X-ray diffraction, chemical analysis, thermal analysis); knowing specialized software for studying crystal morphology & structure and interpreting powder X-ray diffraction data (WinXMorph, JCrystal, KrystalShaper, Kristall2000, VESTA, PowDLL, QualX2).

Skills

The student is able to describe the symmetry & crystal systems, as well as crystal planes using Miller indices; operate a basic powder X-ray diffractometer and interpret indicative X-ray diffraction patterns of simple/basic minerals (e.g. halite, calcite, quartz), relevant rocks (e.g. limestone), selected biominerals (e.g. whewellite) and molecular/organic crystals (e.g. sucrose); calculate basic structural parameters and unit cell constants; use a polarizing/petrographic microscope and the relevant components (e.g lenses); make a plan for instrumental chemical analysis of minerals & geological materials in different scales; evaluate representative (e.g. of carbonate and sulfate minerals) thermal analysis diagrams.

General competence

The student can formulate an opinion on a scientific problem in a short essay; present a scientific topic in a clear and ordered way; collaborate with others during laboratory work in a constructive manner.

CONTENT

Introduction to Mineralogy and Materials Science; historical aspects; principles of Crystallography and crystal chemistry; crystalline and amorphous solid materials; unit cell and crystal lattice; geometrical/morphological Crystallography (symmetry, crystal systems, Miller indices, crystallographic symbols, enantiomorphism/chirality, stereographic projection); Quasicrystals and related minerals and natural phases; intergrowth and twinning; crystal and mineral nucleation & growth (crystallization), crystal growth inhibition; formation of minerals and growth from melt/magma & hydrothermal solutions, effect of pressure and metamorphic & deep minerals, minerals precipitating in solutions, biominerals; epitaxy, topotaxy, exsolution, phase diagrams; introduction to microscopic techniques (optical microscopy, SEM, TEM, AFM); basic principles of instrumental analysis in mineralogy (X-rays, e^-, p^+, Laser, MS, ion-beams); optical Crystallography-Mineralogy (polarizing/petrographic microscope, optical properties of minerals, refractive index, isotropic/anisotropic, pleochroism, optical axis, uniaxial/biaxial, birefringence/interference color); introduction to Solid-State Chemistry and structural Crystallography-Mineralogy (crystal structure, defects/impurities & color, solid solutions/isomorphism, allotropy, polymorphism, polytypism); X-rays and characterization of materials and minerals by means of powder X-ray diffraction (Bragg's law, X-ray diffraction patterns, unit cell constants); X-ray diffraction using Synchrotron radiation and portable & remote equipments; Thermal behaviour of minerals; thermal analyses (TGA, DTA, DSC); introduction to selective -free- software (WinXMorph http://cad4.cpac.washington.edu/WinXMorphHome/WinXMorph.htm; JCrystal & KrystalShaper http://jcrystal.com/; Kristall2000 http://www.kristall2000.de/ ; VESTA

https://jp-minerals.org/vesta/en/; PowDLL http://users.uoi.gr/nkourkou/powdll/; QualX2 http://www.ba.ic.cnr.it/softwareic/qualx/).

TEACHING AND LEARNING METHODS

– Lectures/seminars
– Laboratory work using mineral crystals, X-ray diffractometer, optical microscopes, analytical instruments, and exercises using specialized software (WinXMorph, JCrystal & KrystalShaper, Kristall2000, VESTA, PowDLL, QualX2).
– Homework essays

INFORMATION AND MULTIMEDIA

Licensed access for students to Course Notes etc. in the website of the department (http://eclass.uoa.gr/courses/GEOL314) and also free access in personal websites of the coordinator/instructors (http://users.uoa.gr/~agodel/Files/courses.html and https://drive.google.com/file/d/0B1junna0lrM4NGQxOTBiOGEtZWVlMi00ZTE1LTliOWEtOTUzMjY4NzQyNWE1/view); all electronic platforms open for communication, announcements, evaluation, etc.

COURSE STRUCTURE (hrs)

Lectures: 39 (13x3)
Seminars: 25
Laboratory work and exercises: 26 (13x2)
Additional assistance: 10
Homework essays: 50
Total : 150

FORM OF EXAMINATION

Theory and practical examination (written and/or oral) at the end of the Course
To pass the Course, a minimum grade **5** (out of 10) is necessary.

COURSE LITERATURE

Texts in Greek

 ΒΟΛΙΩΤΗΣ Σ.: Εισαγωγή στην Κρυσταλλογραφία και στη Δομική Χημεία, Μέρος Α/Παν/μιο Πατρών 1983 & ΜέροςΒ/Εκδόσεις Βούλγαρη 1987.
 ΓΚΟΝΤΕΛΙΤΣΑΣ Α. - ΠΑΠΟΥΛΗΣ Δ.: Νανογεωεπιστήμες. Εκδόσεις Γκότση 2021.

 ΘΕΟΔΩΡΙΚΑΣ Σ.Σ.: Ορυκτολογία-Πετρολογία, Εκδόσεις Χ. Σαούλη Ο.Ε., 2η Έκδοση, Θεσσαλονίκη 2002.
 ΚΟΚΚΟΡΟΣ Π.: Γενική Ορυκτολογία, Εκδόσεις Δ.Ν. Παπαδήμα, Έκδοσις Θ, Αθήνα 1987.
 ΡΕΝΤΖΕΠΕΡΗΣ Π.: Εισαγωγή στην Κρυσταλλοδομή και τη Φυσική τ ων Α κτίνων Χ & Εργαστηριακές Α σκήσεις, Ε κδ. Γιαχούδη-Γιαπούλη, Θεσσαλονίκη 1985.
 ΣΟΛΔΑΤΟΣ Κ.Τ.: Μαθήματα Ορυκτολογίας, Μέρος Ι-Εισαγωγή στην Κρυσταλλογραφία, Παν/μιο Θεσσαλονίκης 1980.
 ΣΤΕΡΓΙΟΥ Α.Χ.: Μέθοδοι Κρυσταλλοδομής, Εκδ. Ζήτη 2003.
 ΧΡΙΣΤΟΦΙΔΗΣ Γ. - ΣΟΛΔΑΤΟΣ Τ.: Οπτική Ορυκτολογία. Εκδόσεις Γιαχούδη 2012.

Books

BLOSS F.D.: Crystallography and Crystal Chemistry, MSA 2nd printing, Whashington D.C. 2000.
 BROWN D.I.: The Chemical Bond in Inorganic Chemistry, Oxford Univ. Press 2006.
 BROWN M.E. and GALLAGHER P.K. (Eds.): Handbook of Thermal Analysis and Calorimetry, Elsevier 2003.
 DYAR M.D. et al.: Mineralogy and Optical Mineralogy, MSA, Chantilly 2008.
 ECHLIN P.: Handbook of Sample Preparation for Scanning Electron Microscopy and X-ray Microanalysis, Springer 2009.
 EGERTON R.F.: Physical Principles of Electron Microscopy: An Introduction to SEM, TEM and AEM, Springer 2005.
 FENTER P. et al. (Eds.): Applications of Synchrotron Radiation in Low-Temperature Geochemistry and Environmental Science, MSA Reviews in Mineralogy and Geochemistry Vol. 49, 2002.
 KLEIN C. and HURLBUT C.S.Jr.: Manual of Mineralogy (after J.D. Dana), J.Wiley & Sons, revised 21st Edition 1999.
 NESSE W.D.: Introduction to Mineralogy, Oxford Univ. Press 2000.
 PUTNIS A.: Introduction to Mineral Sciences, Cambridge Univ. Press 1992.
 REED S.J.B.: Electron Microprobe Analysis and Scanning Electron Microscopy in Geology, Cambridge Univ. Press, 2nd Ed. 2005.
 SUNAGAWA I.: Crystals: Growth, Morphology and Perfection, Cambridge Univ. Press 2005.

Articles

 Belousova E.A. et al., 2006. Zircon crystal morphology, trace elements signatures and Hf isotope composition as a tool for petrogenetic modelling: Examples from Eastern Australian granitoids. J. Petrol., 47 (2), 329-353.
 Buseck P.R. et al., 2001. Magnetite morphology and life on Mars. PNAS, 98 (24), 13490-13495.
 Clark C.M. and Downs R.T., 2004. Using the American mineralogist crystal structure database in the classroom. J. Geosci. Edu., 52 (1), 76-80.
 Donnay G. and Donnay J.D.H., 1978. How much crystallography should we teach geologists? Am. Mineral., 63, 840-846.
 Dutrow B.L., 2004. Teaching mineralogy from the core to t he crust. J. Geosci. Edu., 52 (1), 81-86.

 Dyar M.D. et al., 2004. Integration of new methods into teaching mineralogy. J. Geosci. Edu., 52 (1), 23-30.
 Fortin D., 2004. What biogenic minerals tell us. Science, 303, 1618-1619.
 García-Ruiz J.M. et al., 2007. Formation of natural gypsum megacrystals in Naica, Mexico. Geology, 35 (4), 327-330.
 Golden D.C. et al., 2004. Evidence for exclusively inorganic formation of magnetite in Martian meteorite ALH84001. Am. Mineral., 89, 681-695.
 Gunter M.E. 2004. The polarized light microscope: Should we teach t he use o f a 1 9th century instrument in the 21st century? J. Geosci. Edu., 52 (1), 34-44.
 Hawthorne F.C., 1993. Minerals, mineralogy and mineralogists: Past, present and future. Can. Mineral., 31 (2), 253-296.
 Hazen R.M., 2005. Genesis: Rocks, minerals and the geochemical origin of life. Elements, 1, 135-137.
 Hazen R.M. et al., 2001. Selective adsorption of l- and d-amino acids on calcite: Implications for biochemical homochirality. PNAS, 98 (10), 5487-5490.
 Hazen R.M. et al., 2008. Mineral evolution – Review paper. Am. Mineral., 93, 1693-1720.
 Hemley R.J., 1999. Mineralogy: Mineralogy at a crossroads. Science, 285, 1026-1027.
 Hildebrandt G. et al., 1993. 80 years X-ray Diffraction: Contribution to a colloquium held on November 5, 1992 in Berlin, Humboldt University. Cryst. Res. Technol., 28 (6), 747- 823.
 Hochella Jr. M.F., 2006. The case for nanogeoscience. Ann. N.Y. Acad. Sci., 1093 (1), 108-122.
 Hochella Jr. M.F. et al., 2008. Nanominerals, mineral nanoparticles and Earth systems. Science, 319, 1631-1635.
 Ihinger P.D. and Zink S.I., 2000. Determination of relative growth rates of natural quartz crystals. Nature, 404, 865.
 Loon A.J., 2008. Geological education of the future. Earth Sci. Rev., 86, 247-254.
 Meunier A., 2006. Why are clay minerals small? Clay Minerals, 41, 551-566.
 Mogk D.W. et al., 2007. On the cutting edge - Teaching mineralogy, petrology and geochemistry. Elements, 3, 93-126.
 Pasteris J.D. et al., 1999. Medical mineralogy as a new challenge to the geologists: Silicates in human mammary tissue? Am. Mineral., 84, 997-1008.
 Pokroy B. et al., 2007. Protein-induced, previously unidentified twin form of calcite. PNAS, 104 (18), 7337-7341.
 Railsback L.B., 2005. A synthesis of systematic mineralogy. Am. Mineral., 90, 1033-1041.
 Ricardo A. et al., 2004. Borate minerals stabilize ribose. Science, 303, 196.
 Rosing M.T., 2008. On the evolution of minerals. Nature, 456, 456-458.
 Sarrazin P. et al., 2005. Field deployment of a portable X-ray diffraction/X-ray fluorescence instrument on Mars analog terrain. Powder Diffr., 20 (2), 128-133.
 Sgualdino G. et al., 1998. Growth morphology of sucrose crystals. The role of glucose and fructose as habit-modifiers. J. Cryst. Growth, 192, 290-299.
 Smith J.V., 1999. Geology, mineralogy and human welfare. PNAS, 96, 3348-3349.
 Swope R .J. a nd G ieré R ., 2 004. A s trategy f or t eaching a n effective undergraduate mineralogy course. J. Geosci. Edu., 52 (1), 15-22.
 Talboys D.L. et al., 2005. Instrumentation for geological field work on the Moon. Earth Moon Planet., 94 (3-4), 267-277.

 Thomas-Keprta K.L. et al, 2001. Truncated hexa-octahedral magnetite crystal in ALH84001: Presumptive biosignatures. PNAS, 98 (5), 2164-2169.
 Vasconcelos C . a nd M cKenzie A ., 2 009. T he descent o f minerals. Science, 323, 218-219.
 Wulff A.H., 2004. Using inquiry-based methodologies to ease the pain of learning mineral formulae and analytical techniques. J. Geosci. Edu., 52 (1), 68-75.

WEBPAGE OF THE COURSE (including Course Notes in .pdf files):

http://eclass.uoa.gr/courses/GEOL314 and http://users.uoa.gr/~agodel/Files/courses.html & https://drive.google.com/file/d/0B1junna0lrM4NGQxOTBiOGEtZWVlMi00ZTE1LTliOWEtOTUzMjY4NzQyNWE1/view)