GUIDE OF THE COURSE

ELECTRONIC MICROSCOPY AND CHARACTERIZATION TECHNIQUES

(updated: 22/10/2019)
Academic year: 2019-20

MODULE	TOPIC	SUBJECT	COURSE	SEMESTER	ECTS	CHARACTER
Common	Electronic Microscopy and Characterization Techniques	Electronic Microscopy and Characterization Techniques	1	1	3	Optative

LECTURERS	CONTACT
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	TUTORING SCHEDULE (link)
	Fernando Vereda: http://fisicaaplicada.ugr.es/pages/profesorado#__doku_titulares_de_universidad
MASTER	
Máster Universitario en Física: Radiaciones, Nanotecnología, Partículas y Astrofísica (Master in Physics: Radiation, Nanotechnology, Particles and Astrophysics)	

PREREQUISITES AND/OR RECOMMENDATIONS
Basic knowledge of: radiation-matter interaction phenomena, the particle/wave duality, the crystal structure of solids and diffraction techniques

BRIEF DESCRIPTION OF CONTENTS

Scanning electron microscopy (SEM) and transmission electron microscopy (TEM). Atomic force microscopy (AFM). Instrumentation in microscopy. Instrumentation in structure analysis.

OBJECTIVES

The student will know/understand:

- The principles behind the operation of the two main types of electron microscopes (scanning electron microscopes and transmission electron microscopes) as well as those behind an atomic force microscope to the extent that he/she should be able to operate electron or atomic force microscopes, perhaps with minor supervision.

***The student will be able to*:**

1. Decide what technique should be used to study/characterize a given material
2. Understand and interpret microscopy results (bright field and dark field images, electron diffraction patterns, STEM-HAADF, high resolution images, backscattered-electron or secondary-electron SEM images) and results from related techniques, such as energy-dispersive X-ray (EDX) spectroscopy, electron energy loss spectroscopy (EELS) or X-ray diffraction (XRD)

CONTENTS OF THE COURSE

- **Lecture 1**: Introduction. Limits of optical microscopy.
- **Lecture 2**: Interactions between electrons and solids. Elastic scattering and diffraction. Bragg's Law, reciprocal lattice and Ewald's Sphere.
- **Lecture 3**: Interactions between electrons and solids. Inelastic scattering and the *thick sample*. Secondary and backscattered electrons. Elemental analysis: energy-dispersive X-ray (EDX) spectroscopy and wavelength dispersive X-ray spectroscopy (WDXS). Electron energy loss spectroscopy (EELS).
- **Lecture 4**: SEM: image formation. Environmental SEM. Electron Backscattered Diffraction (EBSD)
- **Lecture 5**: TEM: image formation and basic techniques: mass-thickness contrast, bright field (BF) and dark field (DF) contrast. Phase contrast and high resolution (HRTEM and UHRTEM), scanning transmission electron microscopy (STEM-HAADF), electron tomography in TEM, selected area electron diffraction (SAED).
- **Lecture 6**: Instrumentation: electron guns, detectors, lenses, apertures. Sample preparation.
- **Lecture 7**: AFM. Basic components and modes of operation; topography and phase images; force measurements and other applications

Students will participate in 3 sessions (SEM, TEM and AFM) at the microscopes of the 'Centro de Instrumentación Científica' de la UGR

REFERENCES

- J. Mittemeijer and Udo Welzel (Ed), "Modern diffraction methods", Wiley-VCH, 2013.
- B. Fultz y J. Howe. "Transmission Electron Microscopy and Diffractometry of Materials". 4ª Edición. Springer 2013.
- J. Mittemeijer and Udo Welzel (Ed), "Modern diffraction methods", Wiley-VCH, 2013.
- Qiang Wu, Fatima A. Merchant, Kenneth R. Castleman, "Microscope image processing", Elsevier/Academic Press, 2008.
- A. W. Robards, A. J. Wilson (Ed), "Procedures in electron microscopy", John Wiley & Sons , 1993
- Miguel Aballe Carride, José López Ruiz, Paloma Adeva Ramos, José María Badía Pérez, "Microscopía electrónica de barrido y microanálisis por rayos X", CSIC, 1996.
- Joseph I. Goldstein *et al*., "Scanning electron microscopy and X-ray microanalysis", Kluwer Academic, 2003.
- D.B. Williams & C. B. Carter, "Transmission electron microscopy: A textbook for materials science." Ed. Plenum Press, 1996.

- P. Buseck, J Cowley & L. Eyring (Eds.) “High-Resolution Transmission electron microscopy and associated techniques” Ed. Oxford Science Publications, 1992
- P. Buseck (Ed), “Minerals and reactions at the atomic scale: Transmission electron microscopy.” Rev. in Mineralogy, Vol 27. Series Editor: P.H. Ribbe. Mineralogical Society of America, 1992
- G. Haugstad, “Atomic force microscopy: exploring basic modes and advanced applications” John Wiley & Sons, 2012. Electronic resource available at the library of the University of Granada.
- P.C. Braga, D. Ricci, “Atomic force microscopy in biomedical research: Methods and protocols.” Methods in Molecular Biology. Vol. 736. Springer 2011. Electronic resource available at the library of the University of Granada.
- Manuel Rodríguez Gallego, "La difracción de los rayos X", Alhambra, 1982.
- A. Guinier, “X-ray diffraction in crystals, imperfect crystals and amorphous bodies” Dover Publications Inc.,1994

USEFUL LINKS

www.mse.iastate.edu/research/laboratories/sem/microscopy/ (Page of the Iowa State University on SEM)
www.fei.com/introduction-to-electron-microscopy/ (Introduction to electron microscopy by FEI, a microscope manufacturer)
www.matter.org.uk/tem/ (Basic concepts on TEM by the ‘*Matter*’ a consortium of British universities)
www.doitpoms.ac.uk/tlplib/tem/index.php (page of Cambridge University on TEM)
www.doitpoms.ac.uk/tlplib/afm/index.php (page of Cambridge University on AFM)

METHODOLOGY

Lectures: To transmit the contents of the subject, motivating the students to reflection, facilitating the discovery of relationships between different concepts and promoting a critical mindset.

Academic tutoring: To guide the autonomous and team work of students, focusing on different aspects of the subjects and guide the comprehensive academic training of the student.

Experimental classes/demonstrations: To develop experimental skills (sample handling and preparation) and to strengthen the understanding of how the microscopes work.

Study and independent work of students: To foster in the student the ability to self-regulate their learning, by planning, designing, evaluating and adapting it to their particular conditions and interests.

Teamwork: To encourage students in the generation and exchange of ideas, identification and analysis of different views on a topic, generalization or transfer of knowledge and critical assessment of it.