

Academic year	2015-16
Subject	11296 - Transmission Electron Microscopy
Group	Group 1, 1S
Teaching guide	A
Language	English

Subject identification

Subject	11296 - Transmission Electron Microscopy
Credits	0.72 de presencials (18 hours) 2.28 de no presencials (57 hours) 3 de totals (75 hours).
Group	Group 1, 1S (Campus Extens)
Teaching period	First semester
Teaching language	English

Professors

Lecturers	Horari d'atenció als alumnes					
	Starting time	Finishing time	Day	Start date	Finish date	Office
Jaime Pons Morro jaime.pons@uib.es	12:00	14:00	Tuesday	01/09/2015	31/01/2016	F.308 Ed. Mateu Orfila 3r pis
	12:00	14:00	Thursday	01/09/2015	31/01/2016	F.308 Ed. Mateu Orfila 3r pis
	12:00	14:00	Wednesday	01/02/2016	31/07/2016	F.308 Ed. Mateu Orfila 3r pis
	12:00	14:00	Friday	01/02/2016	31/07/2016	F.308 Ed. Mateu Orfila 3r pis
Rubén Santamarta Martínez ruben.santamarta@uib.es	14:30	15:30	Thursday	14/09/2015	18/07/2016	F114 - 1r pis, Ed. Mateu Orfila (imprescindible concertar cita per email)
	14:30	15:30	Wednesday	14/09/2015	18/07/2016	F114 - 1r pis, Ed. Mateu Orfila (imprescindible concertar cita per email)

Contextualisation

Transmission Electron Microscopy (TEM) is a powerful experimental technique for characterization of matter at microscopic scales, ranging from micrometers down to angstroms. This technique provides microstructural information of the object from magnified images, together with crystallographic information arising from the electron diffraction pattern. Moreover, additional spectroscopic techniques attached to the TEM instrument may give useful additional information, such as chemical composition with high spatial resolution (microanalysis). Due to these remarkable capabilities, the set of experimental techniques involved in TEM became an essential tool for the development of Life and Materials Sciences in the last half century. This course aims to provide the basic knowledge for the operation of a transmission electron microscope,

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combining the fundamentals of electron diffraction and image contrast with practical aspects related to the use of the instrument and to the correct interpretation of the large amount of information provided by this technique.

The course 11296 - Transmission Electron Microscopy belongs to the *Experimental Physics* module of the *Master's Degree in Advanced Physics and Applied Mathematics* at UIB, together with other experimental work related subjects. However, the specific nature of this subject creates a direct link with the *Materials Physics* module too. The subject is also included in the *Chemistry and Physics of Materials Speciality* of the *Master's Degree in Chemical Science and Technology* at UIB.

The academic and research background of the lecturers fit perfectly with the topic of the subject. Rubén Santamarta received his PhD in Physics at UIB in 2002. He is a member of the Physics of Materials research group and Associate Professor since 2005, with teaching activity both in undergraduate and graduate levels (Master's degree and PhD program courses). Between 2002 and 2004 held a post-doctoral stay at EMAT (Antwerp, Belgium) to improve his skills in TEM. This is one of the top electron microscopy centers in Europe. Jaume Pons received his PhD in Physics in 1992 and performed a post-doc stay at the Centre d'Etudes de Chimie Metallurgique - CNRS (France) in 1993 for specialization in High Resolution TEM. He became Associate Professor in 1994 and Professor of Applied Physics in 2011. His research activity has always been in the Physics of Materials research group. Both lecturers are experienced users of electron microscopy and diffraction techniques since their PhD work. During these years, more than 120 scientific papers published by these authors in indexed international journals have included results obtained by TEM and related techniques.

Requirements

Essential requirements

Degree in Sciences or Engineering

Recommendable

For those students with no background on electron microscopy techniques, it is strongly recommended to take the subject 11280-*Structural and Microstructural Characterization of Materials* from the Physics of Materials' Module. The 11280 subject provides the basic concepts of electron microscopy and diffraction which are needed for a proper comprehension of the *11296 - Transmission Electron Microscopy* subject.

Skills

Specific

- * CE3 - To acquire edge-line knowledge in the international scientific research context and demonstrate a full comprehension of theoretical and practical aspects, together with the scientific methodology..
- * EX8 - To know the possibilities and limitations of the Transmission Electron Microscopy techniques and acquire skills to analyze and extract information from the rough results provided by the instrument..

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Generic

- * CG1 - Systematic comprehension of a field of knowledge and its related skills and research methods..

Basic

- * You may consult the basic competencies students will have to achieve by the end of the Master's degree at the following address: http://estudis.uib.cat/master/comp_basiques/

Content

Theme content

- 1.. Introduction
General introduction to the instrument and interaction of electrons with matter
- 2.. Sample Preparation
Electropolishing, ion milling, FIB, deposition of nanometric samples
- 3.. Electron Diffraction
Brief revision of the Kinematical Theory of Electron Diffraction. Diffraction modes: SAED, microdiffraction, CBED. Inelastic scattering and Kikuchi patterns. Double diffraction. Dynamical Theory of Electron Diffraction. Different approaches: Wave-Optical formulation (Howie-Whelan equations) and Quantum Mechanical formulation (Bloch waves).
- 4.. Imaging in the TEM
Principles of Image Contrast. Thickness fringes and bending contours. Crystal defects contrast: planar defects, dislocations and volume defects (precipitates).
- 5.. High Resolution TEM
Phase contrast. Formation of images: lens system, specimen, envelope and transfer function. Weak-phase object approximation. Scherzer defocus. Experimental considerations. Simulation of HRTEM images: multislide and Bloch waves methods
- 6.. Spectroscopic Techniques
X-ray spectrometry: basics, Energy Dispersive X-ray Spectrometry (EDX) and Wavelength Dispersive X-Ray Spectrometry (WDX). Qualitative and quantitative EDX microanalysis. Electron Energy Loss Spectrometry (EELS). Energy Filtering Microscopy.
- 7.. Advanced Techniques
Scanning Transmission Electron Microscopy (STEM), Annular Dark Field (ADF), High Angle Annular Dark field (HAADF) and Z contrast. Aberration Corrected Microscopy. In-situ TEM. Lorentz microscopy. Electron holography. Tomography.

Teaching methodology

In-class work activities

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Modality	Name	Typ. Grp.	Description	Hours
Theory classes	Theory classes	Large group (G)	Master classes to introduce the theoretical basis of the course content.	11
Laboratory classes	Laboratory	Medium group (M)	Lab activity about sample preparation, operation of the instrument and image simulations. Most of this work will be performed at the Scientific and Technical facilities Service of the UIB, under the lecturer supervision.	5
Assessment	Oral presentation	Large group (G)	Oral presentation about a proposed theme.	1
Assessment	Short exams	Large group (G)	Written exams composed of short questions about the concepts developed in the classes	1

At the beginning of the semester a schedule of the subject will be made available to students through the UIBdigital platform. The schedule shall at least include the dates when the continuing assessment tests will be conducted and the hand-in dates for the assignments. In addition, the lecturer shall inform students as to whether the subject work plan will be carried out through the schedule or through another way included in the Campus Extens platform.

Distance education work activities

Modality	Name	Description	Hours
Individual self-study	Report	Preparation of a written report on a proposed topic.	37
Individual self-study	Study	Study of the concepts developed in the classes	20

Specific risks and protective measures

The learning activities of this course do not entail specific health or safety risks for the students and therefore no special protective measures are needed.

Student learning assessment

Theory classes

Modality	Theory classes
Technique	Attitude scales (non-retrievable)
Description	Master classes to introduce the theoretical basis of the course content.
Assessment criteria	Attitude and participation in the classes

Final grade percentage: 5%

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Laboratory

Modality	Laboratory classes
Technique	Attitude scales (non-retrievable)
Description	Lab activity about sample preparation, operation of the instrument and image simulations. Most of this work will be performed at the Scientific and Technical facilities Service of the UIB, under the lecturer supervision.
Assessment criteria	Attitude and participation in the classes

Final grade percentage: 5%

Oral presentation

Modality	Assessment
Technique	Oral tests (retrievable)
Description	Oral presentation about a proposed theme.
Assessment criteria	Oral presentation of the report.

Final grade percentage: 25%

Short exams

Modality	Assessment
Technique	Short-answer tests (retrievable)
Description	Written exams composed of short questions about the concepts developed in the classes
Assessment criteria	Written exams composed of short questions about the concepts developed in the classes

Final grade percentage: 25%

Report

Modality	Individual self-study
Technique	Papers and projects (retrievable)
Description	Preparation of a written report on a proposed topic.
Assessment criteria	Written report about a proposed topic

Final grade percentage: 40%

Resources, bibliography and additional documentation

Basic bibliography

D.B. Williams, C. B. Carter. Transmission Electron Microscopy : a textbook for materials science. Plenum Press (1996).

Complementary bibliography

- P. Hirsch, A. Howie, R.B. Nicholson, D.W. Pashley, M.J. Whelan. Electron Microscopy of Thin Crystals. Robert Krieger Publishing Co. (1977)
- L. Reimer. Transmission Electron Microscopy : Physics of image formation and microanalysis. 2nd Ed. Springer-Verlag (1989)



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- M. de Graef. Introduction to Conventional Transmission Electron Microscopy. Cambridge univ. Press (2002)

