Syllabus

Subject

Subject / Group	11296 - Transmission Electron Microscopy / 1
Degree	Master's Degree in Advanced Physics and Applied Mathematics Master's Degree in Chemical Science and Technology
Credits	3
Period	First semester
Language of instruction	English

Professors

Lecturers	**Office hours for students**					
	Starting time	**Finishing time**	**Day**	**Start date**	**End date**	**Office / Building**
Jaime Pons Morro jaume.pons@uib.es	You need to book a date with the professor in order to attend a tutoring session.					
Rubén Santamarta Martínez ruben.santamarta@uib.es	11:30	12:30	Thursday	13/09/2018	28/02/2019	Director CEP/ Antoni Maria Alcover i Sureda
	14:30	15:30	Thursday	13/09/2018	28/02/2019	Director CEP/ Antoni Maria Alcover i Sureda

Context

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, 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

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(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

Degree in Sciences or Engineering

Recommended

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

* EX8 - To know the posibilities and limitations of the Transmission Electron Microscopy techniques and adquire skills to analyze and extract information from the rough results provided by the instrument. .
* CE1 - Students must possess the learning skills that enable them to combine specialized knowledge in Astrophysics and Relativity, Geophysical Fluids, Materials Physics, Quantum Systems or Applied Mathematics, with the versatility that provides an open training curriculum. .

Generic

* CB6 - Possess the knowledge and its understanding to provide the basis or opportunity to be original in developing and/or applying ideas, often within a research context. .
* CB7 - Students can apply the broader (or multidisciplinary) acquired knowledge and ability to solve problems in new or unfamiliar environments within contexts related to their field of study. .
* CB10 - Students gain the learning skills that enable them to continue studying in a way that will be largely self-directed or autonomous. .

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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

Range of topics

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 Difraction. Diffraction modes: SAED, microdiffraction, CBED.Inelastic scattering and Kikuchi patterns. Double diffraction. Dynamical Theory of Electron Difraction. 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 aproximation. Scherzer defocus. Experimental considerations. Simulation of HRTEM images: multislide and Bloch waves methods

6.. Spectroscopic Techniques

X-ray spectrometry: basics, Energy Dispersive X-raySpectrometry (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 (0.72 credits, 18 hours)

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

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Modality	Name	Typ. Grp.	Description	Hours
Laboratory classes	Laboratory	Medium group (M)	Lab activity about sample preparation, operation of the instrument and use of simulation software. Most of this work will be peformed at the Scientific and Technical facilities Service of the UIB, under the lecturer supervision.	6
Assessment	Short exams	Large group (G)	Written examcomposed 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 Aula Digital platform.

Distance education tasks (2.28 credits, 57 hours)

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

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

Frau en elements d'avaluació

In accordance with article 33 of Academic regulations, "regardless of the disciplinary procedure that may be followed against the offending student, the demonstrably fraudulent performance of any of the evaluation elements included in the teaching guides of the subjects will lead, at the discretion of the teacher, a undervaluation in the qualification that may involve the qualification of "suspense 0" in the annual evaluation of the subject".

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Laboratory

Modality	Laboratory classes
Technique	Real or simulated task performance tests **(retrievable)**
Description	Lab activity about sample preparation, operation of the instrument and use of simulation software. Most of this work will be peformed at the Scientific and Technical facilities Service of the UIB, under the lecturer supervision.
Assessment criteria	The lecturers will propose a task to be performed by the student or a project related with the laboratory classes to be solved

Final grade percentage: 30%

Short exams

Modality	Assessment
Technique	Short-answer tests **(retrievable)**
Description	Written examcomposed 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: 40%

Report

Modality	Individual self-study
Technique	Papers and projects **(retrievable)**
Description	Elaboration of a written report about a proposed topic.
Assessment criteria	Written report about a topicproposed by the lecturers

Final grade percentage: 30%

Resources, bibliography and additional documentation

Basic bibliography

D.B. Williams, C. B. Carter. Transmission Electron Microscopy : a textbook for materials science. Springer (2009).

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)
- M. de Graef. Introduction to Conventional Transmission Electron Microscopy. Cambridge University Press (2003)

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