UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH

Course guide
2301209 - MCH - Material Characterization

Last modified: 29/05/2025

Unit in charge: Barcelona School of Telecommunications Engineering
Teaching unit: 1004 - UB - (ENG)Universitat de Barcelona.

Degree: MASTER'S DEGREE IN SEMICONDUCTOR ENGINEERING AND MICROELECTRONIC DESIGN (Syllabus 2024). (Optional subject).

Academic year: 2025 **ECTS Credits:** 4.0 **Languages:** English

LECTURER

Coordinating lecturer: BLAS GARRIDO FERNÁNDEZ

Others: Segon quadrimestre:
LORENZO CALVO BARRIO - 11
BLAS GARRIDO FERNÁNDEZ - 11
SERGIO HERNANDEZ MARQUEZ - 11
MANUEL LOZANO FANTOBA - 11
GEMMA RIUS SUÑE - 11
LLUÍS YEDRA CARDONA - 11

LEARNING RESULTS

Knowledges:
KT03. Describe the physical principles underlying current semiconductor devices in relation to their application, as well as their emerging trends, modelling and characterisation techniques.
KT04. Identify and describe the different manufacturing and characterisation processes in microelectronics and their applicability according to the functional and cost requirements of the final integrated product.
KT07. Identify gender stereotypes and roles and how they may impact professional practice.

Skills:
ST06. Plan the different activities involved in successfully carrying out an assigned task within a team, managing time and resources appropriately.

TEACHING METHODOLOGY

Masterclasses and classroom exercises. Practical sessions in the laboratory.

LEARNING OBJECTIVES OF THE SUBJECT

1. Acquire basic knowledge on most common methods, instruments and applications in the characterization of materials in micro/nanoelectronics chips
2. Learn to assess different steps of fabrication technology research, development and production of materials and devices, based on each of the techniques and the respectively provided information
3. Be able to select and apply most appropriate characterization strategy for relevant use cases in micro/nanoelectronics
4. Acquire knowledge and hands on practice of the basic inspection and clean room characterization tools, including optical, mechanical and electrical
5. Acquire knowledge and hands on practice with microscopy and surface analytical tools, being able to extract relevant information

STUDY LOAD

Type	Hours	Percentage
Self study	70,0	70.00
Hours large group	24,0	24.00
Hours small group	6,0	6.00

Total learning time: 100 h

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CONTENTS

Advanced Characterization of Materials, Devices and Processing

Description:
This course is a general introduction to the materials characterization methods, instruments and applications used in conventional semiconductor microelectronics, as well as in emerging nanotechnologies. It describes most common techniques applied to bulk, thin film and nanomaterials, and cover most relevant structural, compositional, morphological and functional aspects for this industry.

Block 1. Inspection and basic clean room characterization

1. Materials and processes; profilometry and mechanical properties (4h IMB Manuel Lozano)
Semiconductor materials for micro/nanoelectronics: synthesis, deposition, processing and production. Exemplary CMOS run for general introductory overview. Mechanical and optical profilometers: thickness profile and roughness measurement. Groove width, depth and pitch. Geometrical characterization, wafer warp and bow and thickness capacitive measurement. Film stress, modulus of elasticity and thermal expansion.

2. Resistivity, carrier density and lifetime (4h IMB Manuel Lozano)
Two- and four-point probes. Resistivity profiling by Differential Hall Effect and Spreading Resistance. Contactless methods. Contact resistance, Schottky barriers and Photocurrent. Defects from C-V and current measurements. Electron Beam Induced Currents (EBIC). Device measurements: High Frequency, low frequency and pulsed MOS capacitor, diode I-V, C-V and gated diode. Hall effect and mobility.

3. Optical microscopy and spectroscopy (4h UB S. Hernández)
Instrumental details and image formation. Optical microscopes. Phase contrast and confocal microscopy. Reflectometry for thickness and absorption. Infrared spectroscopy (FTIR) for quantitative chemical analysis, free carriers, dopants and impurities. Ellipsometry for optical constants and thickness. PL and Raman spectroscopy for band-gap, defects and carrier lifetime.

Block 2. Micro/nanoscopy, structure and chemical composition

4. Atomic Force Microscopy and related techniques (4h IMB Gemma Rius).
Interactions tip-sample. Instrumental details: tips, sensors and feedback, detectors. Image formation and operating modes: contact, tapping and non-contact. Topographic images and roughness analysis. Nanotribology and other mechanical properties. Advanced nanoscale electrical characterization by AFM for conductivity (C-AFM), capacitance (SCM), Kelvin probe (KPFM) or spreading resistance (SSRMS).

5. Electron microscopies (4h UB Lluis Yedra)
Interaction of electrons with matter. Scanning Electron Microscopy (SEM). Topography, morphology, and composition. Coupling with nano preparation SEM-FIB. Analytical SEM: Energy Dispersive X-Ray Spectroscopy (EDS). Transmission Electron Microscopy (TEM). Electron diffraction and image formation. Phase contrast and high resolution (HRTEM). Electron Energy Loss Spectroscopy (EELS).

6. X-Ray Diffraction (XRD) (2h UB Blas Garrido).
Fundamentals of X-Ray scattering and diffraction. Crystalline structure determination. Crystallite size, effects of strain, indexing and peak broadening. Synchrotron diffractometers at ALBA (soft X-rays, SAXS, high resolution)

7. Surface chemical characterization techniques (XPS, SIMS) (4h UB Blas Garrido)
Photoelectric effect induced by X-Rays, chemical states, and chemical shifts. Instrumentation details, X-Ray sources and electron detectors. Static XPS spectrum and composition. Depth profiles and composition. Principles of mass spectrometry. Ionization by different means. Principles of operation of SIMS. Mass analyzers and detection. Depth profiles, quantitative composition. ToF-SIMS. Surface scanning and image formation.

Lab sessions

1. Session with wafer inspection, profilometry & electrical characterization techniques (3h IMB – Clean Room Gemma Rius)
2. Session of characterization with optical spectroscopy EQE-Raman-FTIR-UV-VIS-PL (3h UB Sergi Hernández & Blas Garrido)

Specific objectives:
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micro/nanoelectronics chips
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3. Be able to select and apply most appropriate characterization strategy for relevant use cases in micro/nanoelectronics
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Related activities:
Practicum with instrumentation in the laboratory

Full-or-part-time: 32h
Theory classes: 32h

GRADING SYSTEM

Exam and practical work (50% and 50%)

BIBLIOGRAPHY

Basic:

- Runyan, W.R.. Semiconductor measurements and instrumentation. 2nd ed. New Yok: McGrawhill, 1975. ISBN 9780070542730.
- Schroder, D.K. Semiconductor material and device characterization. 3rd ed. Wiley-IEEE Press, 2016. ISBN 9780471739067.
- Vickerman, J.C. ToF SIMS: materials analysis by mass spectrometry. IM Publications, 2012. ISBN 9781906715175.
- Celano, U. Electrical atomic force microscopy for nanoelectronics. Cham: Springer, 2019. ISBN 9783030156145.