MSE8016: MATERIALS CHARACTERIZATION TECHNIQUES

Effective Term
Semester A 2025/26

Part I Course Overview

Course Title
Materials Characterization Techniques

Subject Code
MSE - Materials Science and Engineering
Course Number
8016

Academic Unit
Materials Science and Engineering (MSE)

College/School
College of Engineering (EG)

Course Duration
One Semester

Credit Units
3

Level
R8 - Research Degree

Medium of Instruction
English

Medium of Assessment
English

Prerequisites
Nil

Precursors
Nil

Equivalent Courses
Nil

Exclusive Courses
Nil

Part II Course Details

Abstract

This course introduces the fundamental theoretical framework underlying the techniques and instrumentation used in characterizing structural, compositional, and surface properties of materials. The focus is on the acquisition of knowledge of characterization of materials properties and their corresponding physics, instrumentation consideration, strength, and limitations. Virtual laboratory session will be conducted for the selected analytical techniques.

Topics covered: Scanning Electron Microscopy (SEM), Energy Dispersive X-ray Spectroscopy (EDS), Transmission Electron Microscopy (TEM), Scanning Probe Microscopy (SPM), Scanning Tunnelling Microscopy (STM), Atomic Force Microscopy (AFM), Electron Energy Loss Spectroscopy, X-Ray Photoelectron Spectroscopy (XPS), Auger Electron Spectroscopy (AES), Neutron Diffraction, X-ray Diffraction, Electron Diffraction, etc.

Course Intended Learning Outcomes (CILOs)

	CILOs	Weighting (if app.)	DEC-A1	DEC-A2	DEC-A3
1	Describe the characteristics of analytical instruments for advanced materials, such as their sensitivities, spectral resolution, spatial resolution, depth of analysis, etc.	25		x	
2	Describe the various types of materials characterization techniques, and be able to relate them to the principles of fundamental physics and chemistry.	30	x	x	
3	Select advanced analytical techniques and apply them to characterization of different materials and nanomaterials under various analysis conditions.	25	x	x	x
4	Analyze, interpret and mutually correlate data to arrive at meaningful conclusions.	20	x		x

A1: Attitude
Develop an attitude of discovery/innovation/creativity, as demonstrated by students possessing a strong sense of curiosity, asking questions actively, challenging assumptions or engaging in inquiry together with teachers.

A2: Ability
Develop the ability/skill needed to discover/innovate/create, as demonstrated by students possessing critical thinking skills to assess ideas, acquiring research skills, synthesizing knowledge across disciplines or applying academic knowledge to real-life problems.

A3: Accomplishments
Demonstrate accomplishment of discovery/innovation/creativity through producing /constructing creative works/new artefacts, effective solutions to real-life problems or new processes.

Learning and Teaching Activities (LTAs)

	LTAs	Brief Description	CILO No.	Hours/week (if applicable)
1	Lectures	Explain key concepts, such as the foundation of knowledge in modern methodologies of materials characterization and their applications	1, 2, 3, 4	2hrs/wk

2	Tutorials	Quizzes related to fundamental knowledge; data analysis and interpretation such as determination of chemical and phase composition, crystal structure	1, 2, 3, 4	1hr/wk
3	Term Paper	Write a report to select suitable characterization techniques to obtain structural, chemical, and morphological information on materials	1, 2, 3, 4	
4	Digital Lab Report	Write a lab report after virtual laboratory session. Describe the experimental procedures and answer related questions about selected characterization techniques.	1, 2, 3, 4	

Assessment Tasks / Activities (ATs)

	ATs	CILO No.	Weighting (%)	Remarks ("-" for nil entry)	Allow Use of GenAI?
1	Assignments	1, 2, 3, 4	10	-	Yes
2	Term paper	1, 2, 3, 4	10	-	Yes
3	Midterm test	1, 2, 3, 4	20	-	No
4	Digital Lab Report	1, 2, 3, 4	10	-	Yes

Continuous Assessment (%)

50

Examination (%)

50

Examination Duration (Hours)

2

Assessment Rubrics (AR)

Assessment Task

Assignments (applicable to students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter)

Criterion

Ability to understand and explain the relevant materials

Excellent

(A+, A, A-) High

Good

(B+, B, B-) Significant

Fair
(C+, C, C-) Moderate

Marginal
(D) Basic

Failure
(F) Not even reaching marginal levels

Assessment Task
Midterm test (applicable to students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter)

Criterion
Ability to understand and explain the relevant materials

Excellent
(A+, A, A-) High

Good
(B+, B, B-) Significant

Fair
(C+, C, C-) Moderate

Marginal
(D) Basic

Failure
(F) Not even reaching marginal levels

Assessment Task
Term Paper (applicable to students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter)

Criterion
Ability to select suitable characterization techniques to obtain structural, chemical, and morphological information of materials

Excellent
(A+, A, A-) High

Good
(B+, B, B-) Significant

Fair
(C+, C, C-) Moderate

Marginal
(D) Basic

Failure
(F) Not even reaching marginal levels

Assessment Task
Final Examination (applicable to students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter)

Criterion
Ability to understand and explain the relevant materials

Excellent
(A+, A, A-) High

Good
(B+, B, B-) Significant

Fair
(C+, C, C-) Moderate

Marginal
(D) Basic

Failure
(F) Not even reaching marginal levels

Assessment Task
Assignments (applicable to students admitted from Semester A 2022/23 to Summer Term 2024)

Criterion
Ability to understand and explain the relevant materials

Excellent
(A+, A, A-) High

Good
(B+, B) Moderate

Marginal
(B-, C+, C) Basic

Failure
(F) Not even reaching marginal levels

Assessment Task
Midterm test (applicable to students admitted from Semester A 2022/23 to Summer Term 2024)

Criterion
Ability to understand and explain the relevant materials

Excellent
(A+, A, A-) High

Good
(B+, B) Moderate

Marginal
(B-, C+, C) Basic

Failure
(F) Not even reaching marginal levels

Assessment Task
Term Paper (applicable to students admitted from Semester A 2022/23 to Summer Term 2024)

Criterion
Ability to select suitable characterization techniques to obtain structural, chemical, and morphological information of materials

Excellent
(A+, A, A-) High

Good
(B+, B) Moderate

Marginal
(B-, C+, C) Basic

Failure
(F) Not even reaching marginal levels

Assessment Task
Final Examination (applicable to students admitted from Semester A 2022/23 to Summer Term 2024)

Criterion
Ability to understand and explain the relevant materials

Excellent
(A+, A, A-) High

Good
(B+, B) Moderate

Marginal
(B-, C+, C) Basic

Failure
(F) Not even reaching marginal levels

Assessment Task
Digital Lab Report (Applicable to students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter)

Criterion
Ability to describe procedures and precautions of selected characterization techniques

Excellent

(A+, A, A-)High

Good
(B+, B, B-)Significant

Fair
(C+, C, C-)Moderate

Marginal
(D)Basic

Failure
(F)Not even reaching marginal levels

Assessment Task
Digital Lab Report (Applicable to students admitted from Semester A 2022/23 to Summer Term 2024)

Criterion
Ability to describe procedures and precautions of selected characterization techniques

Excellent
High(A+, A, A-)

Good
Moderate(B+, B)

Marginal
Basic(B-, C+, C)

Failure
(F)Not even reaching marginal levels

Part III Other Information

Keyword Syllabus

- General classification of analytical techniques based on the detection source.
- Scanning electron microscopy (SEM). Environmental SEM. Energy dispersive X-ray spectroscopy (EDS).
- Crystallography and diffraction. Real and reciprocal space.
- Transmission electron spectroscopy (TEM). Bright and dark field imaging. High-resolution TEM (HRTEM). Selected area diffraction (SAD).
- Analytical techniques associated with TEM, Electron energy loss spectroscopy (EELS). Energy dispersive x-ray spectroscopy integrated (EDS) in TEM.
- Auger electron spectroscopy (AES). Scanning Auger spectroscopy (SAM). X-ray photoelectron spectroscopy (XPS).
- X-ray Diffraction.
- Neutron Diffraction.
- Scanning probe microscopy (SPM). Atomic force microscopy (AFM). Scanning tunneling microscopy (STM).

Reading List

Compulsory Readings

	Title
1	Lecture Notes

Additional Readings

	Title
1	X-Ray Diffraction for Materials Research: From Fundamentals to Applications, by Myeongkyu Lee (2017)
2	Transmission Electron Microscopy A Textbook for Materials Science, by David B. Williams, C. Barry Carter (2009)
3	Transmission Electron Microscopy and Diffractometry of Materials, by Brent Fultz, James How (2008)
4	Magnetic neutron diffraction (1st edition), Plenum Press, New York, by Yurii A. Izyumov, Ruslan P. Ozerov (1970)
5	A Beginners' Guide to Scanning Electron Microscopy, by Anwar UI-Hamid (2018)
6	Scanning Electron Microscopy: Physics of Image Formation and Microanalysis, by Ludwig Reimer (1998)
7	Auger Electron Microscopy: Practical Application to Materials Analysis and Characterization of Surface, Interfaces, and Thin Films, by John Wolstenholme (2015)
8	Advanced Transmission Electron Microscopy: Imaging and Diffraction in Nanoscience, by Jian Min Zuo, John C.H. (2017)
9	Scanning Probe Microscopy: Atomic Force Microscopy and Scanning Tunneling Microscopy, by Bert Voigtländer (2016)