PHY5501: MODERN CHARACTERIZATION TECHNIQUES FOR MATERIALS PHYSICS

Effective Term

Semester A 2025/26

Part I Course Overview

Course Title

Modern Characterization Techniques for Materials Physics

Subject Code

PHY - Physics

Course Number

5501

Academic Unit

Physics (PHY)

College/School

College of Science (SI)

Course Duration

One Semester

Credit Units

3

Level

P5, P6 - Postgraduate Degree

Medium of Instruction

English

Medium of Assessment

English

Prerequisites

Nil

Precursors

Nil

Equivalent Courses

AP5301 Instrumental Methods of Analysis and Laboratory

Exclusive Courses

PHY8501 Modern Characterization Techniques for Materials Physics

Part II Course Details

Abstract

This is a survey course for discussing both the physical principles and practical applications of modern methods for materials characterization. The course is designed for graduate students in applied physics and engineering disciplines related to materials research. The goal is to provide students with a foundation in the use of characterization techniques to solve and diagnose material problems that can be identified and potentially resolved with materials characterization.

The course covers techniques of microstructural analysis (OM, SEM, TEM, electron diffraction, XRD), microchemical characterization (EDS, XPS, AES, SIMS, RBS, and Raman spectroscopy), various scanning probe microscopy techniques (AFM, STM, EFM, and MFM) as well as electrical (Hall, CV, Seebeck) and optical measurements (UV-Vis-NIR, Ellipsometry, PL, etc). It emphasizes on the information that can be obtained together with the advantages and limitations of each technique. The course has a laboratory component with written lab reports and a term paper.

Course Intended Learning Outcomes (CILOs)

	CILOs	Weighting (if app.)	DEC-A1	DEC-A2	DEC-A3
1	Describe the physical principles of various analytical instruments.			x	
2	Apply physical principles to the structural design of each element of the instruments, in particular to those involving electron beam and ion beam.			x	
3	Apply selected analytical techniques to common applications.		x		x
4	Develop an in-depth knowledge in selected techniques and how they can be applied to specific problems in research in materials physics		x	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	Introduce various techniques, explain the relevant concepts and applications	1, 2, 3	3
2	Term paper	Apply the knowledge to solve practical problems.	1, 2, 3, 4	
3	Laboratories	Conduct relevant experiments to obtain practical understanding on selected techniques	1, 2, 3, 4	

Assessment Tasks / Activities (ATs)

	ATs	CILO No.	Weighting (%)	Remarks ("-" for nil entry)	Allow Use of GenAI?
1	Laboratories	1, 2, 3, 4	30	-	Yes
2	Term paper	1, 2, 3, 4	20	-	Yes

Continuous Assessment (%)

50

Examination (%)

50

Examination Duration (Hours)

2

Assessment Rubrics (AR)

Assessment Task

Laboratories and Term Paper (for students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter)

Criterion

Evaluate students' practical abilities, analysis, and writing skills. Laboratory assessment examines experimental methods, data handling, report quality, and lab conduct, while term paper evaluation focuses on research quality, analysis, organization, and writing.

Excellent

(A+, A, A-) High (Demonstrates exceptional experimental work and analysis with outstanding documentation and critical thinking.)

Good

(B+, B, B-) Significant (Shows competent experimental work with accurate analysis and well-structured documentation.)

Fair

(C+, C, C-) Moderate (Exhibits adequate experimental work with basic analysis and satisfactory documentation.)

Marginal

(D) Basic (Shows minimal competence with incomplete analysis and poor organization.)

Failure

(F) Not reaching marginal levels (Displays insufficient work with inadequate analysis and documentation.)

Assessment Task

Final Examination (for students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter)

Criterion

Evaluates students' understanding of course content, analytical reasoning, and problem-solving abilities. Assessment focuses on theoretical knowledge, practical applications, and critical thinking skills through both computational and conceptual questions.

Excellent

(A+, A, A-) High (Demonstrates comprehensive mastery of concepts, provides detailed solutions, shows exceptional analytical skills and creative problem-solving.)

Good

(B+, B, B-) Significant (Shows solid understanding, provides clear solutions, applies concepts correctly with minor errors.)

Fair

(C+, C, C-) Moderate (Demonstrates basic understanding, provides adequate solutions, shows some analytical ability with occasional errors.)

Marginal

(D) Basic (Shows minimal understanding, provides incomplete solutions, makes frequent errors in concept application.)

Failure

(F) Not reaching marginal levels (Shows insufficient understanding, provides incorrect or missing solutions, fails to demonstrate basic concept knowledge)

Assessment Task

Laboratories and Term Paper (for students admitted from Semester A 2022/23 to Summer Term 2024)

Criterion

Evaluate students' practical abilities, analysis, and writing skills. Laboratory assessment examines experimental methods, data handling, report quality, and lab conduct, while term paper evaluation focuses on research quality, analysis, organization, and writing.

Excellent

(A+, A, A-) High (Demonstrates exceptional experimental work and analysis with outstanding documentation and critical thinking.)

Good

(B+, B) Significant (Shows competent experimental work with accurate analysis and well-structured documentation.)

Marginal

(B-, C+, C) Moderate to basic (Exhibits adequate or minimal experimental work with basic analysis and satisfactory documentation.)

Failure

(F) Not reaching marginal levels (Displays insufficient work with inadequate analysis and documentation.)

Assessment Task

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

Criterion

Evaluates students' understanding of course content, analytical reasoning, and problem-solving abilities. Assessment focuses on theoretical knowledge, practical applications, and critical thinking skills through both computational and conceptual questions.

Excellent

(A+, A, A-) High (Demonstrates comprehensive mastery of concepts, provides detailed solutions, shows exceptional analytical skills and creative problem-solving.)

Good

(B+, B) Significant (Shows solid understanding, provides clear solutions, applies concepts correctly with minor errors.)

Marginal

(B-, C+, C) Moderate (Demonstrates basic understanding, provides adequate solutions, shows some analytical ability with occasional errors.)

Failure

(F) Not reaching marginal levels (Shows insufficient understanding, provides incorrect or missing solutions, fails to demonstrate basic concept knowledge)

Part III Other Information

Keyword Syllabus

- Materials characterization
- Overview of analytical techniques
- Microscopy
- Spectroscopy
- Optical microscopy
- Electron microscopy: scanning and transmission
- Scanning probe microscopy
- Electron probe microanalysis
- X-ray diffraction
- Ion beam techniques
- Secondary ion mass spectrometry
- Rutherford backscattering spectrometry
- Hall effect
- Capacitance-voltage measurement
- Seebeck effect
- Spectrophotometry
- Spectroscopic ellipsometry
- Modulated spectroscopy
- Photoluminescence
- X-ray photoelectron spectroscopy

Reading List

Compulsory Readings

	Title
1	Encyclopedia of Materials Characterization, edited by C Richard Brundle Charles A Evans, Jr, and Shaun Wilson, Butterworth-Heinemann (1992)

Additional Readings

	Title
1	X-ray Microanalysis in the Electron Microscope (4th Edition), by J A Chandler, North Holland (1987)
2	Methods of Surface Analysis: Techniques and Applications, edited J M E Walls, Cambridge University Press (1990)
3	Analysis of Microelectronic Materials and Devices, edited by M. Grasserbauer and H W Werner, John Wiley & Sons (1991)
4	Dopants and Defects in Semiconductors, Matthew D. McCluskey and Eugene E. Haller, Taylor & Francis Group (2012).
5	Principles and Applications of Ion Beam Techniques for the Analysis of Solids and Thin Films, W. K. Chu, J. W> Mayer, M-A. Nicolet, T. M. Buck, G. Amsel, and F. Eisen, Thin Solid Films 17 1-41 (1973).
6	Secondary Ion Mass Spectrometry, by Benninghoven Rudenauer and Werner, John Wiley & Sons (1987)

7	Atomic and Nuclear Analytical Methods: XRF, Myssbauer XPS, NAA and Ion-Beam Spectroscopic Techniques, Hem Raj Verma, Springer (2007).