# MSE4179: ADVANCED MATERIALS CHARACTERIZATION AND ITS INDUSTRIAL APPLICATIONS

**Effective Term**
Semester B 2025/26

## Part I Course Overview

**Course Title**
Advanced Materials Characterization and its Industrial Applications

**Subject Code**
MSE - Materials Science and Engineering
**Course Number**
4179

**Academic Unit**
Materials Science and Engineering (MSE)

**College/School**
College of Engineering (EG)

**Course Duration**
One Semester

**Credit Units**
3

**Level**
B1, B2, B3, B4 - Bachelor's Degree

**Medium of Instruction**
English

**Medium of Assessment**
English

**Prerequisites**
MSE3171 Materials Characterization

**Precursors**
Nil

**Equivalent Courses**
Nil

**Exclusive Courses**
Nil

# Part II Course Details

**Abstract**

Advanced Materials Characterization Techniques play a vital role in exploring the properties and performance of new materials used in a wide range of industrial sectors, e.g., semiconductor, energy materials, chemical engineering, construction, information technology, and aerospace. This course introduces modern characterization methods that use photons (light and X-rays), electrons, and other techniques to analyze materials in detail, revealing their crystal structure, electronic and optical properties, electrical transport, mechanical and other physical behaviors. Students will learn to apply and interpret data from cutting-edge tools (e.g., synchrotron X-rays, advanced electron microscopy, ultrafast spectroscopy, and phonon-based techniques) to solve complex problems relevant to industrial applications. This knowledge guides the students to choose the suitable characterization techniques to investigate the targeted structure of functional materials and understand their structure-property relationship in industrial applications.

**Course Intended Learning Outcomes (CILOs)**

| | CILOs | Weighting (if app.) | DEC-A1 | DEC-A2 | DEC-A3 |
|---|---|---|---|---|---|
| 1 | Describe the fundamental principles, analytical capabilities, and limitations (e.g., sensitivity, spectral resolution, spatial resolution) of advanced photon-, electron-, and phonon-based characterization instruments. | | x | | |
| 2 | Compare advanced materials characterization methods and select suitable techniques for analyzing crystal structures, electronic structures, and optical, electrical, magnetic, and mechanical properties. | | | x | |
| 3 | Apply advanced characterization techniques effectively to analyze functional materials under various experimental conditions relevant to real-world industrial scenarios. | | | x | x |
| 4 | Interpret and integrate data from multiple characterization methods to reach valid conclusions, and clearly communicate these results through structured technical reports and presentations in professional and industrial contexts. | | 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 | Provide theoretical foundations and operational principles of advanced photon, electron, and phonon-based characterization techniques, highlighting their use in determining intrinsic material properties and industrial relevance. | 1, 2, 3, 4 | 3 hrs/ wk |
| 2 | Tutorial | Explanation of homework tasks related to fundamental knowledge; interpretation of data from various techniques with emphasis on their relevance industrial applications. | 1, 2, 3, 4 | 1 hr/ wk |
| 3 | Laboratory | Demonstration of three important materials characterization techniques. | 1, 2, 3, 4 | 3 hrs/wk |

**Assessment Tasks / Activities (ATs)**

| | ATs | CILO No. | Weighting (%) | Remarks ("-" for nil entry) | Allow Use of GenAI? |
|---|---|---|---|---|---|
| 1 | Homework | 1, 2, 3, 4 | 15 | - | No |
| 2 | Midterm tests | 1, 2, 3, 4 | 20 | - | No |
| 3 | Lab Reports | 1, 2, 3, 4 | 15 | - | No |

**Continuous Assessment (%)**

50

**Examination (%)**

50

**Examination Duration (Hours)**

2

**Minimum Examination Passing Requirement (%)**

30

**Additional Information for ATs**

For a student to pass the course, at least 30% of the maximum mark for the examination must be obtained.

**Assessment Rubrics (AR)**

**Assessment Task**

1.Homework, Midterm exam

**Criterion**

Achievements in CILO

**Excellent (A+, A, A-)**
High

**Good (B+, B, B-)**
Significant

**Fair (C+, C, C-)**
Moderate

**Marginal (D)**
Basic

**Failure (F)**
Not even reaching the marginal leave

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**Assessment Task**
2. Lab reports

**Criterion**
Achievements in CILO

**Excellent (A+, A, A-)**
High

**Good (B+, B, B-)**
Significant

**Fair (C+, C, C-)**
Moderate

**Marginal (D)**
Basic

**Failure (F)**
Not even reaching the marginal leave

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**Assessment Task**
3. Final exam

**Criterion**
Achievements in CILO

**Excellent (A+, A, A-)**
High

**Good (B+, B, B-)**
Significant

**Fair (C+, C, C-)**
Moderate

**Marginal (D)**

Basic

**Failure (F)**

Not even reaching the marginal leave

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# Part III Other Information

**Keyword Syllabus**

- Photon-Based Techniques: Synchrotron X-ray Diffraction (XRD), Grazing Incidence Wide-Angle X-ray Scattering (GIWAXS), X-ray Absorption (XAS) and X-ray Fluorescence (XRF), Circular dichroism Spectroscopy (CD), Circularly polarized luminescence Spectroscopy (CPL), Ultrafast Pump-Probe Spectroscopy.
- Electron-Based Techniques: Transmission Electron Microscopy (TEM), Scanning Transmission Electron Microscopy (STEM), Electron Energy Loss Spectroscopy (EELS), Scanning Electron Microscopy (SEM), Energy-Dispersive X-ray Spectroscopy (EDX).
- Other Techniques: Raman Spectroscopy, Mechanical Testing, Surface Characterization, Thermal and Stability Characterization, In Situ and Operando Techniques.

**Reading List**

**Compulsory Readings**

| | Title |
|---|---|
| 1 | Lecture Notes |

**Additional Readings**

| | Title |
|---|---|
| 1 | P. Willmott, 2019, An Introduction to Synchrotron Radiation: Techniques and Applications, John Wiley & Sons. |
| 2 | A. Rodger, B. Nordén, Circular Dichroism and Linear Dichroism, 1997, Oxford University Press. |
| 3 | T. Mori, Circularly polarized luminescence of isolated small organic molecules, 2020, Singapore: Springer. |
| 4 | O. Svelto, S. De Silvestri, G. Denardo, Ultrafast Processes in Spectroscopy, 1996, Springer. |
| 5 | D. B. Williams, C. B. Carter, 2009, Transmission Electron Microscopy A Textbook for Materials Science, Second Edition. |
| 6 | L.Reimer, H. Kohl, 2008, Transmission Electron Microscopy: physics of image formation, Fifth Edition. |
| 7 | L. Reimer, Scanning electron microscopy: Physics of Image Formation and Microanalysis, 1998, Springer Series in Optical Sciences. |
| 8 | E. Smith, G. Dent, Modern Raman Spectroscopy – A Practical Approach, 2005, John Wiley & Sons. |
| 9 | E. Gdoutos, M. Konsta-Gdoutos, Mechanical Testing of Materials, 2024, Springer. |
| 10 | J. Vickerman, I. Gilmore, Surface Analysis – The Principal Techniques, 2009, John Wiley & Sons. |
| 11 | M. Wagner, Thermal Analysis in Practice, 2018, Elsevier. |
| 12 | A. Ziegler, H. Graafsma, X. Zhang, J. Frenken, In-situ materials characterization, 2014, Springer Series in Materials Science. |