MSE8015: THEORY AND PRACTICE OF TRANSMISSION ELECTRON MICROSCOPY AND RELATED SPECTROSCOPY

Effective Term
Semester B 2025/26

Part I Course Overview

Course Title
Theory and Practice of Transmission Electron Microscopy and Related Spectroscopy

Subject Code
MSE - Materials Science and Engineering
Course Number
8015

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

The basic mathematics tools, Fourier transform and Convolution to illustrate the electron diffraction and imaging theory of transmission electron microscopy (TEM) will be first introduced. The Abbe microscopy theory and lens aberration in Fourier optics will be discussed. Several imaging modes at atomic resolution such as high-resolution TEM (HRTEM) and scanning TEM (STEM) in parallel and focus beam modes, respectively, will be discussed in detail. The physics of electron Beam-Sample Interaction that gives the structural signal and radiation damage will be explained. The electron beam effect on the dose (rate) dependent in-situ TEM experiment will be explored in detail. The theory of electron tomography, energy-dispersive X-ray spectroscopy (EDX), electron energy-loss spectroscopy (EELS), and electron magnetic circular dichroism (EMCD) will be lectured. Virtual laboratory session will be conducted for TEM and related spectroscopy.

Course Intended Learning Outcomes (CILOs)

	CILOs	Weighting (if app.)	DEC-A1	DEC-A2	DEC-A3
1	Describe the mathematics tools such as Fourier transform and convolution. Describe Abbe imaging theory and aberration theory and Fourier optics.		x	x	
2	Describe electron beam-sample interaction of elastic scattering and inelastic scattering with radiation damages.			x	x
3	Analyze crystallographic structure via electron diffraction			x	
4	Describe imaging modes and imaging interpretation of bright-field/dark-Field TEM, atomic-resolution HRTEM, STEM, in-situ TEM, and electron tomography.		x	x	
5	Atomic-resolution spectroscopy of EELS, EMCD, and EDX.			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	Students will engage in formal lectures to gain knowledge about Fourier optics, Abbe microscopy imaging, electron beam sample interaction, atomic resolution imaging of parallel and focused beams, radiation damage, in-situ TEM, high spatial/ temporal resolution TEM	1, 2, 3, 4, 5	2 hours/wk
2	Tutorial	Students will engage in in-depth discussions on the topics of TEM techniques and instrumentation, as well as the Q&A sessions of the homework assignments.	1, 2, 3, 4, 5	1 hours/wk
3	Digital Lab Report	Write a lab report after virtual laboratory session. Describe the experimental procedures and answer related questions about TEM and related spectroscopy.	1, 2, 3, 4, 5	

Assessment Tasks / Activities (ATs)

	ATs	CILO No.	Weighting (%)	Remarks ("-" for nil entry)	Allow Use of GenAI?
1	Assignments	1, 2, 3, 4, 5	15	-	Yes
2	Midterm test	1, 2, 3, 4, 5	25	-	No
3	Digital Lab Report	1, 2, 3, 4, 5	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

Understanding and becoming familiar with mathematical tools and theories in the field of electron optics and advanced electron microscopy

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 levels

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

Criterion
Understanding of the imaging theory and electron beam-sample interaction

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 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 TEM and related spectroscopy.

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

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

Criterion

Understanding the good, the bad, and the ugly of each imaging mode and the fundamental physics for future trends of atomic resolution electron microscopy

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 levels

Assessment Task

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

Criterion

Understanding and becoming familiar with mathematical tools and theories in the field of electron optics and advanced electron microscopy

Excellent

(A+, A, A-) High

Good

(B+, B) Moderate

Marginal

(B-, C+, C) Basic

Failure

(F) Not even reaching the marginal levels

Assessment Task

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

Criterion

Understanding of the imaging theory and electron beam-sample interaction

Excellent
(A+, A, A-) High

Good
(B+, B) Moderate

Marginal
(B-, C+, C) Basic

Failure
(F) Not even reaching the 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 TEM and related spectroscopy.

Excellent
(A+, A, A-) High

Good
(B+, B) Moderate

Marginal
(B-, C+, C) Basic

Failure
(F) Not even reaching marginal levels

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

Criterion
Understanding the good, the bad, and the ugly of each imaging mode and the fundamental physics for future trends of atomic resolution electron microscopy

Excellent
(A+, A, A-) High

Good
(B+, B) Moderate

Marginal
(B-, C+, C) Basic

Failure
(F) Not even reaching the marginal levels

Part III Other Information

Keyword Syllabus

- Fourier optics and electron diffraction
- Abbe microscopy theory
- Electron optics and aberration theory
- Elastic scattering and inelastic scattering
- Mass-thickness contrast and diffraction contrast in transmission electron microscopy (TEM)
- High resolution TEM, scanning TEM, and in-situ TEM
- Electron Tomography
- Advanced spectroscopic techniques: electron energy-loss spectroscopy, electron magnetic circular dichroism, and energy dispersive X-ray spectroscopy.

Reading List

Compulsory Readings

	Title
1	Lecture Notes

Additional Readings

	Title
1	D. B. Williams & C. B. Carter, 2009 Transmission Electron Microscopy A Textbook for Materials Science
2	L. Reimer & H. Kohl 2008 Transmission Electron Microscopy: physics of image formation
3	R.F. Egerton 2011 Electron Energy-Loss Spectroscopy in the Electron Microscope