City University of Hong Kong
Course Syllabus

offered by Department of Materials Science and Engineering
with effect from Semester A 2024/25

Part I Course Overview

Course Title:	**Theory and Practice of Transmission Electron Microscopy and Related Spectroscopy**
Course Code:	**MSE8015**
Course Duration:	**One Semester**
Credit Units:	**3**
Level:	**R8**
Medium of Instruction:	**English**
Medium of Assessment:	**English**
Prerequisites: *(Course Code and Title)*	**Nil**
Precursors: *(Course Code and Title)*	**Nil**
Equivalent Courses: *(Course Code and Title)*	**Nil**
Exclusive Courses: *(Course Code and Title)*	**Nil**

Part II Course Details

1. Abstract

The basic mathematics tools, Fourier transform and Convolution to illustrate the imaging theory of transmission electron microscopy (TEM) will be first introduced. The Abbe microscopy theory and lens aberration in Fourier optics will be discussed. The physics of electron Beam-Sample Interaction that gives the structural signal and radiation damage will be explained. 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 electron beam effect on the dose (rate) dependent in-situ TEM experiment will be explored in detail. Following the above topics, the theory and practice of the future trend of high space/time resolution TEM for atomic resolution dynamics will be discussed in depth. In the end, the theory of energy-dispersive X-ray spectroscopy (EDX), electron energy-loss spectroscopy (EELS), and electron magnetic circular dichroism (EMCD) will be lectured.

2. Course Intended Learning Outcomes (CILOs)

(CILOs state what the student is expected to be able to do at the end of the course according to a given standard of performance.)

No.	CILOs	Weighting* (if applicable)	Discovery-enriched curriculum related learning outcomes (please tick where appropriate)		
			A1	*A2*	*A3*
1.	Describe the mathematics tools such as Fourier transform and convolution. Describe Abbe Imaging Theory and Aberration Theory and Fourier Optics.		√	√	
2.	Describe Electron Beam-Sample Interaction: Elastic Scattering and In-elastic Scattering, Signal and / Radiation Damage and atomic Resolution Spectroscopy: EELS, EMCD, and EDX			√	√
3.	Analyze of Structure via Diffraction Pattern			√	
4	Describe Imaging Modes and Imaging Interpretation: Bright Field/ Dark Field, Atomic Resolution in HRTEM and STEM modes. In-Situ Transmission Electron Microscopy: Seeing and Believing is Wrong. What do we control to get it right? Dose vs Dose Rate		√	√	
5	High Space/ Time Resolution Electron Microscopy: The theory and practice of atomic resolution dynamics for materials science			√	√
	** If weighting is assigned to CILOs, they should add up to 100%.*	100%			

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.

3. Learning and Teaching Activities (LTAs)

(LTAs designed to facilitate students' achievement of the CILOs.)

LTA	Brief Description	CILO No.					Hours/week (if applicable)
		1	2	3	4	5	
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 Focus Beams, Radiation Damage, In-Situ Electron Microscopy, High Space/ Time Resolution TEM…	√	√	√	√	√	2 hours/wk
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 hours/wk

4. Assessment Tasks/Activities (ATs)

(ATs are designed to assess how well the students achieve the CILOs.)

Assessment Tasks/Activities	CILO No.					Weighting *	Remarks
	1	2	3	4	5		
Continuous Assessment: _50___%							
Assignments	√	√	√	√	√	15	
Midterm test	√	√	√	√	√	35	
Examination: (duration: 2 hours)	√	√	√	√	√	50	
** The weightings should add up to 100%.*						100%	

5. Assessment Rubrics

(Grading of student achievements is based on student performance in assessment tasks/activities with the following rubrics.)

Applicable to students admitted before Semester A 2022/23 and in Semester A 2024/25 & thereafter

Assessment Task	Criterion	Excellent (A+, A, A-)	Good (B+, B, B-)	Fair (C+, C, C-)	Marginal (D)	Failure (F)
1. Assignments	Understanding and becoming familiar with mathematical tools and theories in the field of electron optics and advanced electron microscopy	High	Significant	Moderate	Basic	Not even reaching the marginal levels
2. Midterm	Understanding of the imaging theory and electron beam-sample interaction	High	Significant	Moderate	Basic	Not even reaching the marginal levels
3. Examination	Understanding the good, the bad, and the ugly of each imaging mode and the fundamental physics for future trends of atomic resolution electron microscopy	High	Significant	Moderate	Basic	Not even reaching the marginal levels

Applicable to students admitted from Semester A 2022/23 to Summer Term 2024

Assessment Task	Criterion	Excellent (A+, A, A-)	Good (B+, B)	Marginal (B-, C+, C)	Failure (F)
1. Assignments	Understanding and becoming familiar with mathematical tools and theories in the field of electron optics and advanced electron microscopy	High	Moderate	Basic	Not even reaching the marginal levels
2. Midterm	Understanding of the imaging theory and electron beam-sample interaction	High	Moderate	Basic	Not even reaching the marginal levels
3. Examination	Understanding the good, the bad, and the ugly of each imaging mode and the fundamental physics for future trends of atomic resolution electron microscopy	High	Moderate	Basic	Not even reaching the marginal levels

Part III Other Information (more details can be provided separately in the teaching plan)

1. Keyword Syllabus

(An indication of the key topics of the course.)

- Fourier Optics
- Abbe Microscopy Theory
- Electron Optics and Aberration Theory
- Elastic Scattering and In-elastic Scattering
- Dose, Dose Rate and Radiation Damage
- High Resolution Electron Microscopy and Scanning Transmission Electron Microscopy
- Electron Beam Effect on In-Situ Electron Microscopy
- High Space/Time-Resolved Electron Microscopy
- Advanced Spectroscopic Techniques: Electron Energy-Loss Spectroscopy, Electron Magnetic Circular Dichroism, and Energy Dispersive X-ray Spectroscopy.

2. Reading List

2.1 Compulsory Readings

(Compulsory readings can include books, book chapters, or journal/magazine articles. There are also collections of e-books, e-journals available from the CityU Library.)

1.	Lecture Notes

2.2 Additional Readings

(Additional references for students to learn to expand their knowledge about the subject.)

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