City University of Hong Kong  
Course Syllabus  

offered by Department of Materials Science and Engineering  
with effect from Semester A 2023/24

Part I  Course Overview

<table>
<thead>
<tr>
<th>Course Title:</th>
<th>Theory and Practice of Transmission Electron Microscopy and Related Spectroscopy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Course Code:</td>
<td>MSE8015</td>
</tr>
<tr>
<td>Course Duration:</td>
<td>One Semester</td>
</tr>
<tr>
<td>Credit Units:</td>
<td>3</td>
</tr>
<tr>
<td>Level:</td>
<td>R8</td>
</tr>
<tr>
<td>Medium of Instruction:</td>
<td>English</td>
</tr>
<tr>
<td>Medium of Assessment:</td>
<td>English</td>
</tr>
<tr>
<td>Prerequisites:</td>
<td>Nil</td>
</tr>
<tr>
<td>(Course Code and Title)</td>
<td></td>
</tr>
<tr>
<td>Precursors:</td>
<td>Nil</td>
</tr>
<tr>
<td>(Course Code and Title)</td>
<td></td>
</tr>
<tr>
<td>Equivalent Courses:</td>
<td>Nil</td>
</tr>
<tr>
<td>(Course Code and Title)</td>
<td></td>
</tr>
<tr>
<td>Exclusive Courses:</td>
<td>Nil</td>
</tr>
<tr>
<td>(Course Code and Title)</td>
<td></td>
</tr>
</tbody>
</table>
Part II  Course Details

1. Abstract
The basically mathematics tools, Fourier transform and Convolution to illustrate the imaging theory of electron microscopy will be firstly 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 in parallel (HRTEM) and focus beam modes will be discussed in detail. The electron beam effect on the dose (rate) dependent in-situ TEM experiment will be explored in detail. Finally, 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 atomic resolution EDX and EELS 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.)

<table>
<thead>
<tr>
<th>No.</th>
<th>CILOs</th>
<th>Weighting* (if applicable)</th>
<th>Discovery-enriched curriculum related learning outcomes (please tick where appropriate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Describe the mathematics tools: Fourier transform and Convolution</td>
<td>A1</td>
<td>√</td>
</tr>
<tr>
<td>2.</td>
<td>Describe Abbe Imaging Theory and Aberration Theory and Fourier Optics</td>
<td>A2</td>
<td>√</td>
</tr>
<tr>
<td>3.</td>
<td>Describe Electron Beam-Sample Interaction: Elastic Scattering and In-elastic Scattering, Signal and / Radiation Damage</td>
<td>A3</td>
<td>√</td>
</tr>
<tr>
<td>4.</td>
<td>Analyze of Structure via Diffraction Pattern</td>
<td></td>
<td>√</td>
</tr>
<tr>
<td>5.</td>
<td>Describe Imaging Modes and Imaging Interpretation: Bright Field/ Dark Field, Atomic Resolution in HRTEM and STEM modes</td>
<td></td>
<td>√</td>
</tr>
<tr>
<td>6.</td>
<td>In-Situ Transmission Electron Microscopy: Seeing and Believing is Wrong. What do we control to get it right? Dose vs Dose Rate</td>
<td></td>
<td>√</td>
</tr>
<tr>
<td>8.</td>
<td>Atomic Resolution Spectroscopy: EELS and EDX</td>
<td></td>
<td>√</td>
</tr>
</tbody>
</table>

* 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 self-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. Teaching and Learning Activities (TLAs)
(TLAs designed to facilitate students’ achievement of the CILOs.)

<table>
<thead>
<tr>
<th>TLA</th>
<th>Brief Description</th>
<th>CILO No.</th>
<th>Hours/week (if applicable)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lectures</td>
<td>Detail Theory on 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…</td>
<td>√</td>
<td>2 hours/ wk</td>
</tr>
<tr>
<td>Tutorial</td>
<td>Home work</td>
<td>√</td>
<td>1 hours/ wk</td>
</tr>
</tbody>
</table>

4. Assessment Tasks/Activities (ATs)
(ATs are designed to assess how well the students achieve the CILOs.)

<table>
<thead>
<tr>
<th>Assessment Tasks/Activities</th>
<th>CILO No.</th>
<th>Weighting</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous Assessment: <em>30</em>_%</td>
<td>1 2 3 4 5 6 7 8</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>Midterm test</td>
<td>√</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Examination: (duration: 2 hours)</td>
<td>√</td>
<td>70</td>
<td></td>
</tr>
</tbody>
</table>

* 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 in Semester A 2022/23 and thereafter**

<table>
<thead>
<tr>
<th>Assessment Task</th>
<th>Criterion</th>
<th>Excellent (A+, A, A-)</th>
<th>Good (B+, B)</th>
<th>Marginal (B-, C+, C)</th>
<th>Failure (F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Midterm</td>
<td>Understanding of the imaging theory and electron beam-sample interaction</td>
<td>High</td>
<td>Moderate</td>
<td>Basic</td>
<td>Not even reaching the marginal levels</td>
</tr>
<tr>
<td>2. Examination</td>
<td>Understanding of the good, the bad and the ugly of each imaging mode and the fundamental physics for future trend of atomic resolution electron microscopy</td>
<td>High</td>
<td>Moderate</td>
<td>Basic</td>
<td>Not even reaching the marginal levels</td>
</tr>
</tbody>
</table>

**Applicable to students admitted before Semester A 2022/23**

<table>
<thead>
<tr>
<th>Assessment Task</th>
<th>Criterion</th>
<th>Excellent (A+, A, A-)</th>
<th>Good (B+, B, B-)</th>
<th>Fair (C+, C, C-)</th>
<th>Marginal (D)</th>
<th>Failure (F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Midterm</td>
<td>Understanding of the imaging theory and electron beam-sample interaction</td>
<td>High</td>
<td>Significant</td>
<td>Moderate</td>
<td>Basic</td>
<td>Not even reaching the marginal levels</td>
</tr>
<tr>
<td>2. Examination</td>
<td>Understanding of the good, the bad and the ugly of each imaging mode and the fundamental physics for future trend of atomic resolution electron microscopy</td>
<td>High</td>
<td>Significant</td>
<td>Moderate</td>
<td>Basic</td>
<td>Not even reaching the marginal levels</td>
</tr>
</tbody>
</table>
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

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.
   2.
   3.
   ...

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Course Syllabus
Jun 2017