**750-360 Electron Microscopy and Diffraction**

**Spring 2023**

L. D. Marks, B03 Catalysis Center, 1-3996 **L-marks at northwestern.edu**

Class Web Page **www.numis.northwestern.edu/360**

TTh L158 Tech ; Lab to be arranged if possible

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 Office Hours, TBD

There are no prerequisites for this class beyond basic materials science and calculus. If you are not a Materials Science major, and have not had any prior exposure, you need to read up on some basic materials science. Here is a brief list of some things that you should know ahead of time for this class, at least at the level covered in MSE 350-201 or 301:

* What are grains, polycrystalline samples, grain boundaries
* What are dislocations
* What are twins and stacking faults
* Simple definitions of directions and planes in a crystal
* Simple structures such as fcc, bcc

**General (Important) Comments**

This is not a linear course. It has been evolved over the years into a heavily Socratic course, where I show diffraction patterns and images and have the class analyze them. It also relies upon having labs where the students use a TEM and SEM themselves. Obviously labs are going to be a problem. It may be possible in May to run a few ***optional*** hands-on labs, but this is not likely. The current plan is to use existing videos (mainly on YouTube) to cover some parts of the use of microscopes, including these in homework assignments or similar. It may be possible to remotely run several demonstration SEM and TEM labs, although this will depend very heavily upon how lockdowns evolve during the quarter.

**Textbook: None**

**Suggested Reference Books**

* Transmission Electron Microscopy: A Textbook for Materials Science (4 volumes) by David B. Williams, C. Barry Carter, Kluwer (Recommended)
* Transmission Electron Microscopy and Diffractometry of Materials by James M. Howe, Brent Fultz, Springer 2001 (Optional)
* Scanning Electron Microscopy and X-Ray Microanalysis: A Text for Biologists, Materials Scientists, and Geologists by Joseph I. Goldstein, Dale E. Newbury, Patrick Echlin, David C. Joy, Kluwer, (Very Optional)

# Lecture Overview

**I. Basics**

 Description of a microscope (SEM & TEM)

 Source, Lenses, Sample

 Objective Lens

 Detectors

##  Elastic Interactions, Inelastic Interactions

 Sample Preparation

 Waves:

 Fourier Transforms, Fourier Series

 Coherent and Incoherent waves; classical versus reality

 Reading:

 Goldstein et al: Chapter 2

 Williams and Carter: Chapters 5,6,9

 Partial Coherence [Notes](http://www.numis.northwestern.edu/360/Partial%20Coherence.docx)

# II. Incoherent Scattering in an SEM (brief)

 Secondary Electrons and Backscattered Electrons

 Basic contrast mechanisms

 Reading:

 Goldstein et al: Chapter 3

**III. Coherent Scattering in a TEM**

 Real and Reciprocal Space

 Diffraction from Crystals

 Indexing Diffraction Patterns

 Kinematical Theory

 Carter and Williams: Chapters 11,12,18,19,20

 Lecture [Notes](http://www.numis.northwestern.edu/360/kinematical.docx)

**IV. Imaging in a TEM**

 Basics

 Thickness and Bending

 Defects

 Carter and Williams: Chapters 22,23,25

# V. Microanalysis

 Mechanism of x-ray production

 Methods of detection and analysis

 Introduction to Quantitative methods

 Comparison of EDX in TEM & SEM

 Basics of EELS

 Goldstein et al: Chapters 5,6

 Carter and Williams: Chapters 33,34,35

**Project/Term Paper:** At the end of the class students either individually or in groups of 2-3 will present (via Zoom) either a Project Report, or a Term Paper. One of the two is required. A Project would involve work using either SEM or TEM on a topic that the student or students propose; to what extent this is possible cannot as yet be predicted. Term Papers can be either an analysis of a particular problem (SEM or TEM based) including literature and current knowns, known-unknowns and speculations about unknown-unknowns. Alternatively a Wikipedia page can be written. **Abstracts** for these are due 4th May.

**Approximate Schedule (subject to change)**

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| --- | --- | --- | --- |
| Week | Topic | Notes | Lab  |
| 3 April | Experimental Electron Microscopy |  |  |
| 10 April | Basics of Waves, Interference, Ewald Sphere | HW #1 Due 11th | Lab 1 |
| 17 April | Reciprocal Lattice, Basics of diffraction | HW #2 Due 18th | Lab 2 |
| 24 April | Discuss Diffraction Patterns in class | HW #3 Due 25th | Lab 3 |
| 1 May | SEM Basics | HW #4 Due 2nd | Lab 4 |
| 8 May | Discuss Imaging in Class | HW #5 Due 9th | Lab 5 |
| 15 May | Discuss Imaging in Class | HW #6 Due 16th | Project |
| 22 May | Cover EELS, EDX  |  | Project |
| 29 June | Channeling, HREM, Advanced Methods |  | Project |
| 5 June | Project Presentations, date TBD | Paper Due TBD |  |
|  |  |  |  |

**Grading (Provisional)**

 Lab Reports: 25%

 Homework: 25%

 Final Project: 50%

**Philosophy**

 You will hopefully come out of this class with:

 1) Some appreciation about how to use a SEM & TEM to get results relevant to your own research, and understand the results of others.

 2) Some/improved understanding of basic concepts that are important for diffraction and in other areas, for instance reciprocal space.

 3) Some practice in "real" problem solving where you do not know for certain if there is an answer!

 You will **NOT** get a recipe for how to understand any image -- this does not exist.