**465, Spring 2017, TTh 11:00-12:30**

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**Website <http://www.numis.northwestern.edu/465>**

**Prerequisite: 460 or an equivalent course with hands-on TEM experience**

**COURSE DESCRIPTION:** The primary focus of this course is to provide both the fundamental theory as well as hands on practice with the use of transmission electron microscopy for more adavanced imaging and diffraction experiments.

**FUNCTIONAL GOALS:** A student completing this course will have a basic understanding of dynamical electron diffraction and imaging theory for transmission electron microscopy, as well as selected more specialized topics.

**PREREQUISITES:** A requirement for this coarse is an adequate background in transmission electron microscopy from a course such as MSE 460 or 360, or an equivalent elsewhere. It is expected that students will understand basic crystallography and kinematical diffraction, and be reasonably comfortable with using a transmission electron microscope.

**Course Outline (Provisional)**

 **1. Imaging Theory (See** [**Notes**](file:///C%3A%5CUsers%5CLDM%5CDesktop%5C465%5Cimaging.doc)**, which will be updated)**

 Short introduction to HREM imaging, experimental aspects (review)

 Source Coherence, Energy Spread

 Instability sources: vibration, drift

 Resolution, sampling and noise

 Detectors: film and digital

 Coherent and Incoherent imaging

 Definitions of coherence

 Definitions of partial coherence

 Mutual coherence – example of source coherence

 Derivation of linear and non-linear imaging models

 Coherent Aberrations

 Incoherent Aberrations

 Mutual Coherence forms

 Contrast Transfer and Envelopes

 Numerical Methods of Image Analysis

 CTF simulation

 Digital Image Analysis

 More Advanced Issues

 Prefield and Postfield Effects

 Coma-Free Imaging and Related Topics

 Image Localization

 Aberration Correction

**2. Dynamical Diffraction (See** [**Notes**](file:///C%3A%5CUsers%5CLDM%5CDesktop%5C465%5Cproj.doc)**, which will be updated)**

 2-D Model derived from Schroedinger's equation

 Schroedinger's equation in 3D

 Bloch-wave solutions & Dispersion surface

 Bethe Potentials

 Simplification to 2D

 Multislice integration

 Reduction and simplification to atomic-string model

 Channeling solutions: 1s, 2s, 2p….

 Application to HREM Imaging

 Depth variations via channeling model

 Application to Z-contrast

 Isolation of 1s states

 Application to Analytical Electron Microscopy

**3. Advanced Techniques for Solving Structures (Notes to be written)**

 Basics of Direct Methods

 Sigma-1, Triplets and Statistics

 Sayre Equation and Tangent Formula

 Feasible-Set Analysis

 Techniques for solution

 Multigrid Methods

 Structure Completion

 Charge Flipping

 Theoretical Basis

 1s Channelling reduction

 Necessary Conditions

 Application to Surfaces

 Off-zone and related techniques

 Precession Diffraction

 Experimental Aspects

 Limitations

Textbook: None

**Suggested Reference/Reading**

**Transmission Electron Microscopy** by Williams and Carter

 Good because it is fairly new. Does not go into the more advanced topics covered in this class..

**High Resolution Electron Microscopy** by Spence

 Very good coverage of HREM, the later editions being much better than the first. Does not have much information about non-linear imaging.

**Diffraction Physics** by Cowley

 Wonderful chapter on Fourier Transforms, and extensive coverage. A fault is that many of the equations appear rather than being derived.

**Transmission Electron Microscopy** by Reimer

 Very good coverage of most topics, albeit a little difficult to read and find material.

**Electron Microscopy of Thin Films** by Hirsch et al

 The bible, at least for diffraction theory, Bloch waves and low resolution microscopy. Unfortunately it does not contain any material on newer techniques.

**High Energy Electron Diffraction and Microscopy** by Peng et al

 A good coverage of dynamical diffraction, more modern, useful as it has the math for more advanced methods.

**Other**

 Other (literature) references will be provided as appropriate, particularly for the sections on Direct Methods and Surfaces

**Grading**

 Lab Reports: 30%

 Assignments: 30%

 Project: 20% Presentation, 20% written