University of Minnesota  
Department of Chemical Engineering and Materials Science  
MATS 5517: Electron Microscopy  
Spring 2014 Syllabus

Instructor

Primary Instructor  
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Office Hours: W 9-10; F 9-10

Teaching Assistant

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Office Hours: M 4:30-5:30, T 11:30-12:30

Lecture

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<td>MWF</td>
<td>3:35-4:25 PM</td>
<td>120 Amundson Hall</td>
<td>Flannigan</td>
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Course Description

This 3.0 credit course provides an introduction to transmission electron microscopy (TEM) and materials characterization using TEM. Topics include the description and operation of TEMs, electron sources, basics of electron optics, interaction of electrons with the specimen, diffraction and imaging techniques, and microanalysis. The goal of this course is to enable you to understand the fundamentals of TEM and microanalysis and to identify which TEM-based method is best-suited to solve specific problems you encounter in your own research. You will learn about instrumentation, the structure of materials, diffraction physics, optics, and condensed matter physics.

Course Goals, Objectives, and Expectations

Students enrolled in this course will:

- become familiar with the hardware of transmission electron microscopes  
- be able to determine the properties of the electron beam and limits of the instrument  
- learn the basics of image/diffraction pattern formation in the TEM  
- learn about electron/matter interactions and how such processes can be used to quantify properties of the specimen  
- be able to identify which TEM technique is best-suited to solve specific characterization problems  
- understand how specific materials properties affect the electron beam and how this translates into the images/diffraction patterns observed  

It is expected that students will attend lecture, do all the assigned reading, and complete all homework assignments on time.

Course Website
Course information and materials along with your grades and class statistics will be provided on Moodle (https://ay13.moodle.umn.edu). You can also access the course website by logging on through the MyU portal. It is important that you become familiar with Moodle and check the MATS 5517 website daily for updates, messages from the instructor and TA, and other important information.

**Textbooks**


In addition, Williams and Carter have an extensive bibliography of general and specialized TEM books at the end of Chapter 1.

**Homework**

Homework will be posted on the course website on Moodle on Wednesday after lecture and will be due the following Wednesday at the beginning of lecture in class. Homework not turned in at the beginning of lecture will be considered late and will receive a score of zero. Solutions will be posted on the course website on Moodle within 24 hours after Wednesday’s lecture. Each student is required to submit and present their own solutions. Copying or paraphrasing from the web, another source, or another student’s solution or permitting your own solution to be copied or paraphrased is considered cheating. The minimum penalty for all students involved is a zero for that homework.

**Guidelines for preparing and submitting homework**

1. All assignments should be prepared on 8.5” x 11” paper with a clean edge; no spiral notebook paper, please.
2. All sheets of the problem set should be stapled together.
3. Your name and ID number should appear in legible handwriting on the upper right corner of the first page. Your name should appear on each subsequent page.
4. Please clearly label all axes and legends in data plots. Use graph paper or data plotting software (e.g., Excel, Origin, MATLAB, etc.) when preparing data plots.
5. Please number the pages of the homework sequentially.
6. Please clearly show and organize your work for numerical solutions. This aids the grader in following your logic and increases the likelihood of receiving all due credit.

**Examinations**

There will be two in-class midterm exams. There will not be a final exam. The exams are closed-book and closed-note. You are not allowed to have any notes in your possession, on your person, or in your calculator. You may use a scientific calculator (e.g., Casio FX-260). The calculator must not have a text memory, graphing capabilities, or the ability to compute integrals. Examples of unacceptable calculators
include the TI-85 and the Casio-9850. If you are uncertain about the suitability of your calculator, please see Prof. Flannigan prior to the first midterm exam so an assessment can be made. Communication devices (e.g., cell phones, etc.) are not permitted during the examination and must remain out of sight in a sealed backpack/bag.

No exams may be taken before the scheduled time, and no make-up midterm exams will be given. Missed midterm exams will receive a score of zero. In the case of well-documented family emergencies or illness, special arrangements will be made.

**Makeup Work for Legitimate Absences**

Students will not be penalized for absence during the semester due to unavoidable or legitimate circumstances. Such circumstances include verified illness, participation in intercollegiate athletic events, subpoenas, jury duty, military service, bereavement, and religious observances. Such circumstances do not include voting in local, state, or national elections.

[http://policy.umn.edu/Policies/Education/Education/MAKEUPWORK.html](http://policy.umn.edu/Policies/Education/Education/MAKEUPWORK.html)

**Re-grading of Exams and Homework**

Students who wish to have their exam or homework re-graded should submit their request within 24 hours of when it was returned. The request should be made in writing via a cover sheet stapled to the front of the homework or exam, indicating the possible error, and placed in Prof. Flannigan's mailbox in 112 Amundson Hall. **Submitting an altered exam or homework for re-grade is an extremely serious offense and will result in at least a zero for the exam or homework.**

**Determination of Grades**

Final grades will be assigned from a histogram of the final homework and exam scores, which will be determined from the following weighting:

- Homework: 30%
- Midterm 1: 35%
- Midterm 2: 35%

**Class Schedule**

The course is organized into four sections. The first mid-term will occur at the end of the second section, and the second will occur on the last day of lecture.

**I. The Transmission Electron Microscope and Basics of Microscopy**

- The transmission electron microscope
- Electron beam sources
- Vacuum systems, pumps, etc.
- Electron lenses and sources of aberrations
- Electron optics
- Resolution of an imaging system
- Specimen preparation for TEM
- Electron detectors and digital imaging

**II. Electron Diffraction**

- Crystal lattices, reciprocal lattice, structure factors
- Basic crystallography
- Electron diffraction: Kinematical theory
- Electron diffraction: Dynamical theory
- Ewald sphere, relrods, and the deviation parameter
- Diffraction patterns and indexing
- Kikuchi diffraction
• Double diffraction, twins, polycrystalline materials, amorphous materials
• Convergent-beam electron diffraction (CBED)

III. Imaging
• Mass-thickness contrast, amplitude contrast, and phase contrast mechanisms
• Diffraction contrast imaging of defects
• High resolution imaging: Phase contrast
• High resolution imaging: Z-contrast
• Moiré, Lorentz, and holographic imaging
• Digital image processing

IV. Microanalysis
• Fast electrons-specimen interactions
• Physical background for microanalysis: Inelastic electronic scatterings
• Electronic excitations of solids and spectroscopic notation
• Electron energy-loss spectroscopy (EELS)
• Energy-filtered imaging and energy-filtered diffraction
• X-ray microanalysis (EDS)
• Electron-beam-induced specimen damage and contamination

Lecture Schedule
Reading is assigned for each lecture below out of Williams and Carter. The first digit indicates which chapter, and the second indicates which section within that chapter. Where no section number is indicated, the entire chapter is assigned. For example, 6.3 indicates the assigned reading is Chapter 6, Section 3 in Williams and Carter. You are welcome to supplement these reading assignments with similar material found in other textbooks, journal articles, electronic sources, etc. (see the TEM Bibliography at the end of Chapter 1 in Williams and Carter).

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**Statement on Accommodations for Students with Disabilities**

It is University policy to provide reasonable accommodations to students with disabilities. This publication is available in alternate formats to persons with disabilities upon request. Please contact the Disability Services office at 612-626-1333, Room 180 of McNamara Alumni Center to arrange a confidential discussion regarding equitable access and reasonable accommodations. If you are registered with Disability Services and have a current letter requesting reasonable accommodations, contact Prof. Flannigan as early in the semester as possible to discuss how the accommodations will be applied in the course.

[https://diversity.umn.edu/disability/](https://diversity.umn.edu/disability/)

**Statement on Classroom Conduct**

Students are expected to interact with other students and the instructor with courtesy and respect. Students whose behavior is disruptive to other students or to the instructor will be asked to leave. Behavior considered disruptive includes, but is not limited to, talking during lecture, using personal communication devices (talking, texting, emailing, etc.), or any other behavior that results in a deterioration of the learning environment. Students whose behavior suggests the need for counseling or other assistance may be referred to counseling services.

**Email Policy**

In compliance with FERPA and the Minnesota Privacy Act, students must use their University of Minnesota email account for conducting official business with the University of Minnesota. Messages originating from other email addresses will be disregarded.
Statement on Student Academic Integrity and Scholastic Dishonesty

Academic integrity is essential to a positive teaching and learning environment. All students enrolled in University courses are expected to complete coursework responsibilities with fairness and honesty. Failure to do so by seeking unfair advantage over others or misrepresenting someone else’s work as your own can result in disciplinary action. The University Student Conduct Code (http://regents.umn.edu/sites/default/files/policies/Student_Conduct_Code.pdf) defines scholastic dishonesty as follows:

Scholastic Dishonesty: Plagiarizing; cheating on assignments or examinations; engaging in unauthorized collaboration on academic work; taking, acquiring, or using test materials without faculty permission; submitting false or incomplete records of academic achievement; acting alone or in cooperation with another to falsify records or to obtain dishonestly grades, honors, awards, or professional endorsement; altering, forging, misrepresenting, or misusing a University academic record; or fabricating or falsifying data, research procedures, or data analysis.

Within this course, a student responsible for scholastic dishonesty can be assigned a penalty up to and including an “F” for the course. If you have any questions regarding the expectations for a specific assignment or exam, ask.

Appropriate Student Use of Class Notes and Course Materials

Students may not distribute instructor-provided notes or other course materials, except to other members of the same class or with the express (written) consent of the instructor. Instructors have the right to impose additional restrictions on course materials in accordance with copyright and intellectual property law and policy. Students may not engage in widespread distribution or sale of transcript-like notes or notes that are close to verbatim records of a lecture or presentation.

http://policy.umn.edu/Policies/Education/Education/STUDENTRESP.html

Statement on Equity, Diversity, Equal Opportunity, and Affirmative Action

The University shall: (1) provide equal access to and opportunity in its programs and facilities without regard to race, color, creed, religion, national origin, gender, age, marital status, disability, public assistance status, veteran status, sexual orientation, gender identity, or gender expression; (2) advocate and practice affirmative action consistent with law; (3) establish and nurture an environment for faculty, staff, students, and visitors that actively acknowledges and values equity and diversity free from all forms of prejudice, intolerance, and harassment; (4) provide equal educational access to members of underrepresented groups; and (5) promote and support equity and diversity through its academic programs.

http://regents.umn.edu/sites/default/files/policies/Equity_Diversity_EO_AA.pdf

Statement on Academic Freedom and Responsibility

Academic freedom is the freedom, without institutional discipline or restraint, to discuss all relevant matters in the classroom, to explore all avenues of scholarship, research, and creative expression, and to speak or write on matters of public concern as well as on matters related to professional duties and the functioning of the University.


Mental Health and Stress Management

http://www.mentalhealth.umn.edu/
http://www.mentalhealth.umn.edu/stressmgmt/index.html

Use of Personal Electronic Devices in the Classroom

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Using personal electronic devices in the classroom setting can hinder instruction and learning, not only for the student using the device but also for other students in the class. To this end, the University establishes the right of each faculty member to determine if and how personal electronic devices are allowed to be used in the classroom. Students may be directed to turn off personal electronic devices if the devices are not being used for class purposes. Students are not permitted to record any part of a class/lab/other session unless explicitly granted permission by the instructor. If the student does not comply, the student may be asked to leave the classroom.

**Sexual Harassment** ([http://regents.umn.edu/sites/default/files/policies/SexHarassment.pdf](http://regents.umn.edu/sites/default/files/policies/SexHarassment.pdf))

Sexual harassment shall mean unwelcome sexual advances, requests for sexual favors, and/or other verbal or physical conduct of a sexual nature when such conduct has the purpose or effect of unreasonably interfering with an individual’s work or academic performance or creating an intimidating, hostile, or offensive work or academic environment in any University activity or program. Such behavior is not acceptable in the University setting.