MSE 481 SYLLABUS

INSTRUCTOR: Pinshane Huang (pyhuang@illinois.edu)
COURSE TIMES: 12:30–1:50 pm Tuesday and Thursday
OFFICE HOURS: 2:00-3:00 PM Thursdays

COURSE DESCRIPTION: This 3- or 4-credit course focuses on transmission electron microscopy, one of the most powerful and flexible tools to understand materials. The course will cover both theory and practical concepts, and work to build intuition for transmission electron microscopy. We will cover the basic operating principles of the microscope, the physics of electron diffraction and image formation, data interpretation, and electron microscopy experiment design.

COURSE OBJECTIVES: Enable students to…

- Understand the optical components of a TEM
- Describe and predict electron scattering in solids
- Interpret diffraction patterns
- Interpret images including bright and dark field TEM, HR-TEM, and STEM
- Understand the key concepts in advanced TEM techniques including EELS, tomography, high-resolution TEM, X-ray microanalysis, and identify appropriate applications, advantages, and limitations of each technique
- Design a TEM experiment: evaluate which samples can be examined and what can be learned about them, chose which TEM techniques are appropriate, describe what the TEM data might look like and how to interpret it in terms of the experimental goals
- Describe modern TEM experiments and the frontiers of TEM

WHO SHOULD TAKE THIS COURSE: In general, this course can be taken by graduate students or upper-class undergraduates who are interested in learning about electron microscopy. This course is often elected by students who incorporate TEM into their research and would like to develop a theoretical background for their work. In the MatSE department, this course may be taken in preparation for the graduate Qualifying Exam on Electron Microscopy and Diffraction.

PREREQUISITES: The prerequisite is MSE 405 (Microstructure Determination) or equivalent. This course assumes an undergraduate-level understanding of electromagnetism, quantum mechanics, crystal structures, and defects. Also useful: solid state physics and Fourier transforms.

TEXTBOOK: D. Williams and B. Carter, "Transmission Electron Microscopy-A Textbook for Materials Science", Plenum Press, New York, 2nd Edition, 2009
**** This text is available free as an e-book through the University Library. This is a great reference, and I would recommend buying a softcover copy of the text, for $25 through Springer.*

*To access the book **online for free**, either try the link below,*
https://link-springer-com.proxy2.library.illinois.edu/book/10.1007/978-0-387-76501-3

*or search "Williams and Carter" at the library website. Go to the heading "Ebooks by Title and Chapter", then click "Springer Ebooks". This should take you to the Springer site; find the Second Edition, which is light blue. Many of the suggested references are available this way as well. ****

OTHER RECOMMENDED REFERENCES: (available online or as course reserves)

1. B. Fultz and J. Howe, "Transmission Electron Microscopy and Diffractometry of Materials", 4^{th} ed., Springer, 2013. **(highly recommended for this course)**
2. L. Reimer, H. Kohl, "Transmission Electron Microscopy: Physics of Image Formation", 5^{th} ed., Springer, 2008.
3. J. Goldstein et al., "Scanning Electron Microscopy & X-Ray Microanalysis", 3rd ed., Springer, 2003.
4. L. Giannuzzi, "Introduction to Focused Ion Beams", Springer, 2004.
5. J. M. Zuo and J. C. H. Spence, "Advanced Transmission Electron Microscopy", Springer, 2017
6. John Spence, "High-resolution electron microscopy," Oxford University Press, 2013.
7. R.F. Egerton, "Electron Energy Loss Spectroscopy in the Electron Microscope," 3^{rd} ed., Springer 2011.
8. E.J. Kirkland, "Advanced Computing in Electron Microscopy," 2^{nd} ed., Springer 2010.
9. Marc De Graef, "Introduction to Conventional Transmission Electron Microscopy", Cambridge, 2003.
10. P. B. Hirsch et al., "Electron Microscopy of Thin Crystals", Krieger Publishing Company, 1977.

EXPECTATIONS: This course is geared toward teaching you as a scientist to utilize the concepts of electron microscopy to empower your research. As much as possible, this course is built around inquiry-based learning rather than memorization. I want you to know *why*, not just *what*. Interacting in and out of class is important. If you don't understand something, or the problem sets are unreasonably difficult, please tell me. You are expected to read the assigned text before coming to class. Our class lectures are designed to complement, not substitute for the readings, and will generally be at a higher level than the textbook. The homework is the most difficult part of the course and generally requires you to synthesize what you have learned and apply it to new concepts. You should allot plenty of time to complete the problem sets and work in small groups to tackle the problems.

PROBLEM SETS:

Problem sets will be due on Fridays at __________. You will be issued one Late Homework Coupon, which used once during the semester for a 24-hour extension. Otherwise, late problem sets will not be accepted without permission from the instructor. *You are encouraged to collaborate and seek help. But, your write-ups must be in your own words, not copied or paraphrased from your classmates or any other sources. You* ***must acknowledge in writing*** *anyone who you talked to or worked with in order to complete your work.*

You will submit your homework online via Gradescope. It is your responsibility to make sure that scanned homework is legible. After the homework is graded, you will be able to view and get feedback about your work. If you spot an error in the grading, you will have one week from the date the homework was graded to submit a regrade request through Gradescope. More information is available at: https://www.gradescope.com/help#help-center-section-student-workflow

ACCOMMODATIONS:

To obtain disability-related academic adjustments and/or aids, students should contact the course instructor and the Disability Resources and Educational Services (DRES) as soon as possible. To contact DRES, you may e-mail disability@illinois.edu, or visit the DRES website. If you are concerned you have a disability related condition that is impacting your academic progress, academic screening appointments are available on campus that can help diagnose a disability.

ACADEMIC INTEGRITY:

Honesty and integrity are fundamental to our community. Guidelines for academic integrity are detailed in Article 1, Part 4 of the Illinois Student Code. Any confirmed violations of that code will be taken seriously and may result in failure for the course.

3 VS 4 CREDIT HOURS: Students have the option of taking this course for either 3 or 4 credit hours. The 4-credit option for graduate students is designed to incorporate applied skills and a stronger research focus. Students enrolled for 4 credit hours will be required to complete ~5 mini-labs consisting of exercises in data simulation or analysis; they will be graded for completion only. You should consider taking the 4-credit option if some of the following apply to you:

- *You plan to use electron microscopy heavily in your own research*
- *You want to maximize connections between what we are learning in the classroom and the real-world use of a TEM*
- *You enjoy a more in-depth and interactive learning experience*
- *You have enough time in your schedule this semester and feel confident in the prerequisite topics for this course*
- *You are reasonably tech-savvy, as these labs involve a small amount of coding and utilize software that is mostly (but not 100%) user friendly*

I will not sign credit hour changes after the course add/drop deadline.

COURSE TOPICS

THE BASICS:
1. Fundamentals of TEM
2. Inelastic and elastic electron scattering
3. Electron optics
4. Practical Aspects: alignment, sample preparation, and instrumentation

DIFFRACTION:
1. Real and reciprocal space lattices
2. Diffraction indexing and simulation
3. Diffraction contrast imaging

IMAGING:
1. Incoherent imaging: STEM
2. Coherent imaging: TEM
3. Interpreting and simulating CTEM and STEM images

SPECTROSCOPY AND BEYOND:
1. X-ray microanalysis
2. EELS
3. Frontiers of electron microscopy