

Course Description: This course discusses the theory and practice of transmission electron microscopy as applied to heterogeneous material systems. Weekly lectures will be accompanied by key laboratory practical sessions (listed below) on diverse materials. Emphasis will be placed on training students how to use a state-of-the-art analytical STEM for analysis of material structure and composition down to the atomic level.

Schedule: We are scheduled to meet on Monday and Wednesday 12:30 to 1:45. Due to the ongoing COVID-19 pandemic, we will begin the semester in Stage 1, meaning no in-person classes. Thus, lectures will initially be delivered online using Zoom, accessible through d2L. If and when we transition to in-person instruction, classroom instruction will occur in the Kuiper Space Sciences building room 312. Practical instruction will also be conducted remotely using Zoom. If and when we transition to in-person classes, practical instruction will occur in the TEM lab in room 15 of the basement of the Kuiper Space Sciences building.

Instructor: (Prof.) Thomas (Tom) Zega, tzega@lpl.arizona.edu, 520-626-1356, Kuiper Space Sciences, Room 522. Office Hours: by appointment.

Required Textbook: 'Transmission Electron Microscopy' by David Williams and C. Barry Carter (2009, second edition). It is published by Springer and can be downloaded in ebook form from the university library. I will supplement my lectures with material from other resources as well, but I will provide those materials online or in reference form as available.

Course Objectives and Expected Learning Outcomes: The objective of this course is to provide students with an understanding of the theory and practice of electron scattering, image formation, and X-ray and electron energy-loss spectroscopy in the transmission electron microscope. By the end of the course, it is expected that students will be able to align and operate the microscope with minimal assistance and to setup various optical modes to analyze heterogeneous materials. Learning outcomes will be assessed based on class participation, problem sets, laboratory practical work, a mid-term and final written exam.

Class website: All lectures and problem sets will be posted to d2L. Supplemental material for lectures, e.g., journal articles, figures, will also be posted. I will try to have each lecture uploaded prior to class, and I will alert you via email when the lecture is online.

Performance Metrics:

Mid-term exam: 30%

Final exam: 30%

Problem sets and laboratory practical work: 30%

Class participation: 10%

Grading Scale (%):

A ≥ 90

B 80 to 89

C 70 to 79

D 60 to 69

E < 60

Credit is not given for assignments that are turned in late.

- See <https://registrar.arizona.edu/courses-catalog/final-examination-schedule-spring-2021?audience=students&cat1=10&cat2=31> for final-exam regulations and the final

University Policies: All university policies related to the syllabus are available at <https://academicaffairs.arizona.edu/syllabus-policies>

Nondiscrimination and Anti-Harassment Policy: The University of Arizona is committed to creating and maintaining an environment free of discrimination. In support of this commitment, the University prohibits discrimination, including harassment and retaliation, based on a protected classification, including race, color, religion, sex, national origin, age, disability, veteran status, sexual orientation, gender identity, or genetic information. For more information, including how to report a concern, please see: <http://policy.arizona.edu/human-resources/nondiscrimination-and-anti-harassment-policy>

Policies Regarding COVID-19: Face coverings are required in our classroom. Per UArizona's **Administrative Directive**, face coverings that cover the nose, mouth, and chin are required to be worn in all learning spaces at the University of Arizona (e.g., in classrooms, laboratories and studios). Any student who violates this directive will be asked to immediately leave the learning space and will be allowed to return only when they are wearing a face covering. Subsequent episodes of noncompliance will result in a Student Code of Conduct complaint being filed with the Dean of Students Office, which may result in sanctions being applied. The student will not be able to return to the learning space until the matter is resolved.

The [Disability Resource Center](#) is available to explore [face coverings and accessibility considerations](#) if you believe that your disability or medical condition precludes you from utilizing any face covering or mask option. DRC will explore the range of potential options as well as remote course offerings. Should DRC determine an accommodation to this directive is reasonable, DRC will communicate this accommodation with your instructor.

Physical distancing is required in our classroom: During our in-person class meetings, we will respect CDC guidelines, including restricted seating to increase physical distancing. Any student who does not maintain physical distance from others may be asked to immediately leave the learning space. Noncompliance may result in a Student Code of Conduct complaint being filed with the Dean of Students Office, which may result in sanctions being applied.

Classroom attendance:

- If you feel sick or may have been in contact with someone who is infectious, stay home; Except for seeking medical care, avoid contact with others and do not travel
- Notify your instructors if you will be missing an in person or online course.
- [Campus Health](#) is testing for COVID-19; Please call (520) 621-9202 before you visit in person.
- Visit the [UArizona COVID-19](#) page for regular updates.

Disclaimer: The information contained in this course syllabus, other than the grade and absence policies, may be subject to change with reasonable advance notice, as deemed appropriate by the instructor.

Lecture Topics

There is not enough time to cover every chapter in detail. Instead, I will cover some chapters in their entirety, whereas others I will cover select topics. The chapters and topics are listed below. I recommend you read each chapter entirely.

Part 1 (Basics)

- Chapter 1: Introduction to the Transmission Electron Microscope
- Chapter 9: The Instrument
- Chapter 2: Scattering and Diffraction
- Chapter 3: Elastic Scattering
- Chapter 4: Inelastic Scattering and Beam Damage
- Chapter 5: Electron Sources
- Chapter 6: Lenses, Apertures, and Resolution

Part 2 (Diffraction)

- Chapter 11: Diffraction in the TEM
- Chapter 12: Reciprocal Space
- Chapter 16: Diffraction from Crystals
- Chapter 18: Obtaining and indexing parallel-beam diffraction patterns

Part 3 (Imaging)

- Chapter 22: Amplitude Contrast
- Chapter 23: Phase Contrast
- Chapter 25: Planar Defects
- Chapter 27: Weak beam Dark-field Microscopy
- Chapter 28: High-resolution TEM
- Chapter 31: Processing and Quantifying Images

Part 4 (Spectrometry)

- Chapter 32: X-ray Spectrometry
- Chapter 33: X-ray Spectra and Images
- Chapter 34: Qualitative X-ray Analysis and Imaging
- Chapter 36: Spatial Resolution and Minimum Detection
- Chapter 37: Electron energy-loss spectrometers
- Chapter 38: Low-loss Spectra
- Chapter 39: High-loss Spectra
- Chapter 40: Fine Structure

Not in W&C: Scanning Transmission Electron Microscopy

Practical Topics

1. Sample handling/loading, Instrument overview and alignment

2. Image formation and acquisition
3. Diffraction: Convergent beam and selected area
4. High-resolution (phase contrast) imaging
5. Scanning TEM and Aberration-corrected Imaging
6. Energy-dispersive X-ray Spectroscopy
7. Electron energy-loss spectroscopy