Overview. This course and the associated laboratory are designed to introduce you, the student, to the theoretical and applied aspects of transmission electron microscopy (TEM). While the focus of the course will be on conventional TEM, some of the other advanced and modern techniques will also be described to the extent possible. Following an introduction to TEM as a microstructure characterization tool, with examples, we will cover some fundamental aspects of electron beam-material interactions and how the signals therefrom relate to and are utilized in the various techniques. Electrons will be treated as both particles and waves. We will then build upon this background to cover the fundamentals of the instrument and its various operational modes. Following this, we will go into greater depth on the various techniques, such as electron diffraction, imaging, crystal, defect, second phase and interface structure analysis, and spectroscopy. Since TEM requires electron transparent thin foils, we will spend a short time discussing specimen preparation. The laboratory part of the course will include 4-5 experiments on description of the instrument, various operational modes, calibration procedures, electron diffraction, imaging, diffraction contrast, phase and defect analysis and spectroscopy. You will work in groups of 3-4 students in the lab part.

COURSE OUTLINE

1. Introduction
   
   I/1-4, 10
   
   Why use the electron microscope?
   Specimen Preparation
   Wavelength, Resolution and Lens Aberrations
   Depth of Field and Focus
   Electron-Specimen Interactions
   Applications of Transmission Electron Microscopy

2. The Transmission Electron Microscope (TEM)
   
   I/5-9
   
   Layout
   Electron Gun and Filament – Types, Emission and Brightness
   Electron Lenses – Types, Condenser, Objective, Diffraction, Projector, etc.
   Modes of Operation
   Bright Field and Dark Field Imaging, Selected Area Diffraction
   Ray Diagrams

3. Electron Diffraction
   
   II/11-13, 16-21
   
   Geometry of Diffraction, Bragg's Law
   Reciprocal Lattice and Ewald Sphere Construction
   Structure Factor and Intensity
   Types of Patterns
   Ring and Spot Patterns – Analysis and Indexing, Crystal Structure Determination
   Kikuchi Lines – Origin and Formation, Analysis and Applications
Mixed Patterns – Twins, Double Diffraction, Precipitates, Ordered Crystals, Spinodal Decomposition, Determination of Orientation Relationship
Convergent Beam Electron Diffraction (CBED)
Trace Analysis and Habit Plane Determination (Stereographic Projection)

4. **Image Formation and Contrast**

   Kinematical and Dynamical Theories of Diffraction Contrast
   Thickness Fringes, Bend Contours, Extinction Distance
   Contrast and Defect Analysis
   Dislocations – Visibility, Burgers Vector and Character Determination
   Stacking Faults – Intrinsic and Extrinsic Types Characterization and Determination
   Dislocation Loops – Interstitial and Vacancy Types Characterization and Determination
   Low-Angle and High-Angle Boundaries, Moiré Fringes
   Precipitates – Coherent, Semi-coherent and Incoherent
   Ordered Crystals, Antiphase Boundaries

5. **Advanced/Modern Techniques**

   Weak Beam Imaging
   Energy Dispersive X-Ray Microanalysis
   Electron Energy Loss Spectroscopy
   High Resolution Imaging
   Scanning Transmission Electron Microscopy

**LABORATORY EXPERIMENTS**

- Introduction to TEM: layout, components, alignment, operation (2 weeks)
- Calibrations – Camera Length, Rotation, Magnification, Astigmatism (2 weeks)
- Diffraction (2 weeks)
- Bright-field and dark-field imaging (2 weeks).
- Defect analysis – (2 weeks)
- Energy dispersive x-ray spectroscopy (1 week)

**TEXT**


Instructor Lecture notes and supplementary materials will be posted prior to class on canvas.unt.edu

**USEFUL REFERENCES**


**COURSE LEARNING OBJECTIVES**

1. Understand fundamentals of electron specimen interactions
2. Understand the basics of TEM, layout and operational modes
3. Learn about how the various signals translate to the various techniques of diffraction, imaging, phase and defect analysis and spectroscopy
4. The laboratory part of the course is aimed at gaining some proficiency in understanding alignment and operation of the microscope, including diffraction, imaging and spectroscopy.

**COURSE OUTCOMES**

It is expected that as a student, you will integrate both the theoretical treatments of the problems and the knowledge gained through practice in the laboratories. In this manner, you will gain the requisite skills associated with this type of microscopy.
ADMINISTRATIVE MATTERS

Assignments/exams credit allocation

Homework + Lab Assignment 35%
Mid-term and Final Exams 65%
(In-class and Take-Home Exams)

Final Grade Basis

A 88+
B 78-<88
C 68-<78
D 55-<68
F <55

COURSE LABORATORY NOTEBOOK

It is expected that you will bring a bound (not loose leaf paper) notebook to these labs to record your data. An inexpensive composition notebook will suffice ($1-$5). However, you will be expected to keep your results in this notebook.

DISABILITIES ACCOMMODATION

The University of North Texas complies with Section 504 of the 1973 Rehabilitation Act and with the Americans with Disabilities Act of 1990. The University of North Texas provides academic adjustments and auxiliary aids to individuals with disabilities, as defined under the law. Among other things, this legislation requires that all students with disabilities be guaranteed a learning environment that provides for reasonable accommodation of their disabilities. If you believe you have a disability requiring accommodation, please see the instructor and/or contact the Office of Disability Accommodation at 940-565-4323 during the first week of class.

ADDITIONAL POLICIES

Authorized Absences and Extenuating Circumstances

Absences due to extenuating circumstances or participation in sponsored activities (see Absence verification from Dean of Students) must be verified by the Dean of Students. Consideration of such absences will be made for laboratories, but not lectures, and you will be allowed to make-up excused laboratories with the faculty or student assistants. For participation in sponsored activities, you must seek approval prior to the absence. For extenuating circumstances, you have 1 week to contact me and/or the Dean of Students to begin the verification process.

Absence for Religious Holidays

In accordance with state law, a student absent due to the observance of a religious holiday may take examinations or complete assignments scheduled for the day(s) missed, including those missed for travel, within a reasonable time after the absence. The student is responsible to notify the instructor of each class of the date of the anticipated absence as early in the semester as possible. Only holidays or holy days observed by a religion whose place of worship is exempt from property taxation under Section 11.20 of the Tax Code may be included. A student who is excused under this provision may not be penalized for the absence.
Cell Phones: Please remember to turn off phones prior to class.

Dress: According to basic safety standards, you must wear clothing that is safe in the specific laboratories. For example, in all laboratories it is required that you wear close-toed shoes.

Food/Drink: Not permitted in the laboratories.

LATENESS: Lateness will not be tolerated. It is extremely disrespectful to the professor and your fellow students.

Academic misconduct and plagiarism will not be tolerated!