ME 555 Electron Microscopy for Energy and Sustainability: Spring 2025

Time: Mondays 10:05am – 12:35am
Location: **Hudson 201 at 10:05am-12:35pm**
Instructor: Prof. Miaofang Chi
Mechanical Engineering and Materials Science (MEMS)
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Office Hours: Mondays 1pm – 2pm

Syllabus

Section 1: Introduction to S/TEM Techniques
- Overview of S/TEM and its capabilities
- History and evolution of electron microscopy

Section 2: Applications of S/TEM in Energy, Sustainability and Quantum Materials
- Role of S/TEM in Renewable Energy Materials Research
- Case studies: battery materials, catalysts, quantum materials, and photovoltaics

Section 3: An Introduction to Energy Storage
- General overview of energy storage techniques and applications
- The Chemistry of Batteries
- Why interfaces and microscopic insights matter

Section 4: Fundamentals of Optics and Electron Diffraction
- Basic optics in electron microscopy
- Principles of electron diffraction and imaging
- Understanding contrast mechanisms

Section 5: Advanced STEM Imaging Techniques and 4D-STEM
- Principles and applications of STEM imaging
- Various STEM imaging contrast mechanisms and the materials information they provide
- STEM image simulations – Q-STEM
- Introduction to 4D-STEM: concepts, data acquisition and data analysis

Section 6: Chemical Analysis Using EDS and EELS
- Basics of Energy Dispersive X-ray Spectroscopy (EDS)
- Fundamentals of Electron Energy Loss Spectroscopy (EELS)
- Advanced monochromated EELS

Section 7: In Situ S/TEM Techniques
- Principles and benefits of *in situ* TEM
- Applications: studying materials under realistic conditions (heating, electrical biasing, environmental gas, etc.)
- Case studies and recent advances

Section 8: Machine Learning-Assisted Data Analysis in S/TEM (Guest Lecturer)
- Introduction to machine learning (ML) concepts for data analysis
- ML techniques for pattern recognition in S/TEM and detection of trivial signals in EELS
- Future trends in ML integration with S/TEM data

Course Requirements and Expectations:
- **Attendance and Participation:** Attend all class lectures and participate in discussions (40%)
- **Homework Assignments:** Complete simulation and data analysis exercises using specified software (30%)
- **Research Plan:** Develop and submit a 0.5-1-page research outline, including a title, topic, problem statement, objectives, and potential methodology (10%)
- **Student Presentations:** Present literature findings on your proposed research topic, 20mins per presentation, followed by a Q&A (30%)