MATERIALS 724/MECHANICAL 726/ENGPHYS 724/CHEMENG 724

Materials Characterization by Electron/Ion Microscopy

Instructor: Prof. Nabil Bassim, ABB B157, bassimn@mcmaster.ca

Course Schedule: September 4, 2025 - , December 11, 2025, Thursdays 3:30-6:20 pm EST

Office Hours: By appointment.

Course Description:

This course will introduce students to the various concepts of electron microscopy as a method for high resolution characterization of materials microstructures. We will explore topics such as electron optics, electron-sample interactions, image formation interpretation, x-ray microanalysis, focused ion beam optics, atom probe tomography, x-ray microscopy, chemical analysis and applications of these techniques. There will also be a focus on practical applications, such as specimen preparation, and microscope operation in a laboratory environment with video and live demonstrations on techniques in scanning electron microscopy (SEM), focused ion beam microscopy, atom probe tomography, and x-ray tomography. Students will also take in-person laboratory sessions designed to learn to use the SEM at the CCEM with laboratory sessions by the staff of the Canadian Centre for Electron Microscopy (CCEM).

Course Objectives:

Develop an understanding of the working principles and applications of the characterization of materials using Scanning Electron Microscopy, Electron Spectroscopy, Focused Ion Beam Microscopy, Atom Probe Tomography, X-ray microscopy and related techniques.

• Understand the physical principles underlying the processes involved in Electron and Ion and X-ray Microscopy.

• Learn the operating principles of the SEM and follow demonstrations and laboratory sessions of electron microscopy during the practical portion of the course which will take place in person at the CCEM.

Course Materials Delivery:

All lectures will be live and in person. I have set up an MS Teams Channel, where I will will host lecture uploads and all official course material and record sessions.

Some pre-recorded talks related to instrumentation will be made available to the students on the MS Teams Channel. The instructor will attempt to record live talks for industrial students over my Powerpoint Slides from Teams and will make available for remote viewing after the live session. However, Professional audio recordings are not being made, so quality of recordings is not promised to be optimal.

Laboratory sessions are optional for this course. McMaster policies related to presence on campus will be followed closely. Because of recent rules, laboratory sessions will be held in groups of 3, with one instructor for 3 hour sessions.

For additional questions, feel free to email the instructor.

Laboratory Sessions:

Laboratory Sessions will be conducted by Mr. Jhoynner Martinez and Mr. Chris Butcher.

Lab sessions will be held over the course of 6 weeks, starting the week of September 23. Groups of 3 will alternate every two weeks. There will be several slots made available:

Group 1: Mon (Sept 15, Sept 29, Oct 20), 9 am-12 pm

Group 2: Mon (Sept 15, Sept 29, Oct 20), 1 -4 pm

Group 3: Tue (Sept 16, Sept 30, Oct 21), 9 am-12 pm

Group 4: Tue (Sept. 16, Sept 30, Oct 21),1-4 pm

Group 5: Wed (Sept. 17, Oct 1, Oct 22), 9 am-12 pm

Group 6: Wed (Sept. 17, Oct 1, Oct 22), 1-4 pm

Group 7: Thu (Sept. 18, Oct 2, Oct 23) 9 am-12 pm

Group 8: Fri (Sept 19, Oct. 3, Oct 24), 9 am - 12 pm

Group 9: Fri (Sept 19, Oct. 3, Oct 24), 1-4 pm

Group 10: Mon (Sept 22, Oct 6, Oct 27) 9 am-12 pm

Group 11: Mon (Sept 22, Oct 6, Oct 27), 1-4 pm

Group 12: Tue: (Sept 23, Oct 7, Oct 28), 9 am-12 pm

Group 13: Tue: (Sept 23, Oct 7, Oct 28), 1-4 pm pm

Practical SEM examination commences in the week of Nov.3 -7th for Groups 1-9 and Nov 10-12th for Groups 10-13.

Evaluation:

Research Report (10%): Each student will choose a new technique in electron microscopy, X-ray or FIB microscopy to perform a literature review, and write a 5-7 page research report describing this work (1.5 space, including figures and references). This report is due towards the end of the term. The report will have a format template that I will distribute to the class. The focus of the report should be a description of the technique and could include a critical review of the literature, including a discussion of the hardware, operating principles, advantages and drawbacks.

Research Report Presentations (20%): Each student will present the work from the research report on early December in a series of 10-minute presentations. These presentations will be performed live, in-person and will be evaluated later in the course. Evaluation will be based on comprehensiveness, clarity and correctness. Attendance from the class is compulsory.

Mid-term exam (20%): There will be a mid-term on lecture covering concepts taught to end of the lecture class prior to the exam. Students will be evaluated on conceptual understanding and solve a series of microscopy problems in during the class time. Exams will be closed book.

Final Exam (25%): A final exam will take place during finals exam week to encompass the full curriculum of the course. Students will be evaluated on conceptual understanding and solve a series of microscopy problems. Closed book exam.

Laboratory Final Exam (20% plus pass/fail): Each student will perform a series of steps on the JEOL 6610 microscope for the lab instructors to demonstrate their skills in practical aspects of microscopy. Marks will be deducted for mistakes on the scope. Additionally, depending on the evaluation, high scores will clear the student to skip ordinary CCEM training in following terms on microscope use and allow them to sign up for immediate use. Mid-range marks will necessitate more training, and poor marks will require a complete retraining on the SEM in order to be used by the student in the future for research purposes.

Demonstration Attendance (5%): We will hold 3 demonstrations of additional instruments available at CCEM: Focused Ion Beam, Atom Probe Tomography and X-ray CT imaging. Attendance is required and points will be given for showing up.

Basic timeline for the course:

Week 1 (Sept 4): Course introduction and planning
Week 2 (Sept 11): Electron Beam-Specimen Interactions: BSE and SE
Week 3 (Sept 18): Electron Beam-Specimen Interactions: X-rays and Auger electrons – Guest Lecturer Dr. Bhavesh Kamaliya
Week 4 (Sept 25): Electron Sources, Lensing System, Image Formation

Week 5 (Oct 2): Detectors, Aberrations, Q&A
Week 6 (Oct 9): Midterm exam
Week 7 (Oct 16): Reading Week (no class)
Week 8 (Oct 23): X-ray CT imaging (guest speaker Dr. Pardis Mohammadpour)
Week 9 (Oct 30): EDS mapping, special modes and detectors
Week 10 (Nov 6): Focused Ion Beam microscopy
Week 11 (Nov 13): Atom Probe Tomography (guest speaker Dr. Gabe Arcuri)
Week 12 (Nov 20): Electron Backscattered Diffraction
Week 13 (Nov 27): Sample preparation, Q&A
Week 14 & 15 (Dec 4 & 11): Student presentations
Final Exam: During the December exam period

References:

Scanning Electron Microscopy and X-Ray Microanalysis, Joseph Goldstein, Dale Newbury et al.,, 4th edition

Introduction to Focused Ion Beams: Instrumentation, Theory, Techniques and Practice, Giannuzzi and Stevie

Recent advances in focused ion beam technology and applications, MRS Bulletin, 2014

This is a course under development by the instructor; subject matter and evaluation methods are subject to change at the discretion of the instructor.

CONDUCT EXPECTATIONS

As a McMaster graduate student, you have the right to experience, and the responsibility to demonstrate, respectful and dignified interactions within all of our living, learning and working communities. These expectations are described in the *Code of Student Rights & Responsibilities* (the "Code"). All students share the responsibility of maintaining a positive environment for the academic and personal growth of all McMaster community members, **whether in person or online**.

It is essential that students be mindful of their interactions online, as the Code remains in effect in virtual learning environments. The Code applies to any interactions that adversely affect, disrupt, or interfere with reasonable participation in University activities. Student disruptions or behaviours that interfere with university functions on online platforms (e.g. use of Avenue 2 Learn, WebEx or Zoom for delivery), will be taken very seriously and will be investigated. Outcomes may include restriction or removal of the involved students' access to these platforms.

Academic Integrity

You are expected to exhibit honesty and use ethical behaviour in all aspects of the learning process. Academic credentials you earn are rooted in principles of honesty and academic integrity. **It is your responsibility to understand what constitutes academic dishonesty.**

Academic dishonesty is to knowingly act or fail to act in a way that results or could result in unearned academic credit or advantage. This behaviour can result in serious consequences, e.g. the grade of zero on an assignment, loss of credit with a notation on the transcript (notation reads: "Grade of F assigned for academic dishonesty"), and/or suspension or expulsion from the university. For information on the various types of academic dishonesty please refer to the Academic Integrity Policy , located at https://secretariat.mcmaster.ca/university-policies-procedures-guidelines/

The following illustrates only three forms of academic dishonesty:

• plagiarism, e.g. the submission of work that is not one's own or for which other credit has been obtained.

• improper collaboration in group work.

• copying or using unauthorized aids in tests and examinations.

Generative AI: Some Use Permitted

Students may use generative AI for editing, translating, outlining, brainstorming and revising their work throughout the course as long as the use of generative AI is referenced and cited following citation instructions given in the syllabus. Use of generative AI outside the stated use without citation will constitute academic dishonesty. It is the student's responsibility to be clear on the limitations for use and to be clear on the expectations for citation and reference and to do so appropriately.

Authenticity / plagiarism detection

This course may use a web-based service to reveal authenticity and ownership of student submitted work.

All submitted work is subject to normal verification that standards of academic integrity have been upheld (e.g., on-line search, other software, etc.). For more details about McMaster's use of Turnitin.com please go to www.mcmaster.ca/academicintegrity.

ACADEMIC ACCOMMODATION OF STUDENTS WITH DISABILITIES

Students with disabilities who require academic accommodation must contact Student Accessibility Services (SAS) at 905-525-9140 ext. 28652 or sas@mcmaster.ca to make

arrangements with a Program Coordinator. For further information, consult McMaster University's *Academic Accommodation of Students with Disabilities* policy.

ACADEMIC ACCOMMODATION FOR RELIGIOUS, INDIGENOUS OR SPIRITUAL OBSERVANCES (RISO)

Students requiring academic accommodation based on religious, indigenous or spiritual observances should follow the procedures set out in the RISO policy. Students should submit their request to their Faculty Office ***normally within 10 working days*** of the beginning of term in which they anticipate a need for accommodation or to the Registrar's Office prior to their examinations. Students should also contact their instructors as soon as possible to make alternative arrangements for classes, assignments, and tests.

COPYRIGHT AND RECORDING

Students are advised that lectures, demonstrations, performances, and any other course material provided by an instructor include copyright protected works. The Copyright Act and copyright law protect every original literary, dramatic, musical and artistic work, **including lectures** by University instructors

The recording of lectures, tutorials, or other methods of instruction may occur during a course. Recording may be done by either the instructor for the purpose of authorized distribution, or by a student for the purpose of personal study. Students should be aware that their voice and/or image may be recorded by others during the class. Please speak with the instructor if this is a concern for you.

EXTREME CIRCUMSTANCES

The University reserves the right to change the dates and deadlines for any or all courses in extreme circumstances (e.g., severe weather, labour disruptions, etc.). Changes will be communicated through regular McMaster communication channels, such as McMaster Daily News, A2L and/or McMaster email.