MATERIALS 724/MECHANICAL 726/ENGPHYS 724/CHEMENG 724

Materials Characterization by Electron/Ion Microscopy

Instructor: Prof. Nabil Bassim, JHE 258, bassimn@mcmaster.ca, x 24102

Course Schedule: September 14, 2021 - , December 9, 2021, Tuesdays 1-3 pm EST, demos Thursdays, 12-2 pm

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 interpretation, x-ray microanalysis, focused ion beam optics, 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 demonstrations on techniques in scanning electron microscopy (SEM), focused ion beam microscopy, and other techniques during the course term that were recorded by the staff of the CCEM during the pandemic. Students will have the option to 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 and related techniques.

• Understand the physical principles underlying the processes involved in Electron and Ion 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 online broadcast from the CCEM.

Course Materials Delivery:

All lectures and chat room and live interactions/office hours will be held on Teams. Avenue to Learn will host lecture uploads and all official course material.

The course will be delivered in a blended synchronous fashion, with some pre-recorded talks and played live during the session, and some live lectures. All talks will then be available for remote viewing after the live session. The instructor will record the Q&A sessions and placed online as well.

Laboratory sessions will be optional for the student, based on level of comfort of the student to be indoors and on the progress of the pandemic in Hamilton and McMaster policies related to opening and room capacity issues. 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. Masks are required to be worn at all times.

For additional questions, feel free to email the instructor.

Laboratory Sessions:

Lab sessions will be held over a course of 6 weeks, starting the week of September 20. Groups of 3 will alternate every two weeks.There will be several slots made available:

Group 1: Tues (Sept 21, Oct 5, Oct 19) , 9-12 am

Group 2: Wed (Sept. 22, Oct 6, Oct 20) 9-12 am, 1-4 pm

Group 3: Wed (Sept. 22, Oct 6, Oct 20) 1-4 pm

Group 4: Thu: (Sept 23, Oct 7, Oct 21) 9-12 am

Group 5: Thu: (Sept 23, Oct 7, Oct 21) 1-4 am

Group 6: Fri (Sept 24, Oct. 8, Oct 22): 9-12 am

Group 7: Tues (Sept 28, Oct 12, Oct 26) 9-12 am

Group 8: Wed (Sept 29, Oct 13, Oct 27) 9-12 am

Group 9: Wed (Sept 29, Oct 13, Oct 27) 1-4 pm

Group 10: Thu (Sept 30, Oct 14, Oct 28) 9-12 am

Group 11: Thu (Sept 30, Oct 14, Oct 28) 1-4 pm

Group 12: Fri (Oct 1, Oct 15, Oct 29) 9-12 am

Evaluation: (Lab option/No Lab option)

Research Report (20% Lab option/20% No lab option): Each student will choose a new technique in electron microscopy or FIB microscopy to perform a literature review, and write a 10 page research report describing this work (~10 pages – 1.5 space, including figures and references). This report is due on at the end of the term. The report should resemble a journal

paper. The focus of the report should be a description of the technique and and could a critical review of the literature, including a discussion of the hardware, operating principles, advantages and drawbacks.

Research Report Presentations (20%/20%): Each student will present the work from the research report on early December in a series of 10-minute presentations. Depending on the state of the pandemic, this could be done live, in-person, or online and will be evaluated later in the course. Evaluation will be based on comprehensiveness, clarity and correctness.

Mid-term exam (20%/25%): There will be a mid-term on lecture covering concepts taught to end of the lecture class. Students will be evaluated on conceptual understanding and solve a series of microscopy problems in an online timeframe devoted to the exam. Exam will be open book but should apply concepts to image analysis, solving a microscopy problems or a quantitative analysis.

Final Exam (30%/35%): 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 in an online timeframe devoted to the exam. Exam will be open book but should apply concepts to image analysis, solving a microscopy problem or a quantitative analysis.

Laboratory Final Exam (10% plus pass/fail/0%): 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.

Basic timeline for the course:

- Week 1 (Sept 14): Course Outline, introduction; planning
- Week 2 (Sept 21): Goldstein Chapter 1,2 : Electron Beam-Specimen Interactions: Backscatter Electrons and Secondary Electrons
- Week 3 (Sept 28): Goldstein Chapters 3,4: Electron Beam-Specimen Interactions: Secondary Electrons and X-rays
- Week 4 (Oct 5): Goldstein Chapters 5,6: The lensing system, sources, brightness; detectors, image formation
- Week 5: (Oct. 12) Mid-term exam
- Week 6: (Oct. 19): Goldstein Chapter 4, Other Inelastic Processes (Auger, X-ray generation)

- Week 7: (Oct. 26): Elements of Goldstein Chapters 16-20: EDS: Qualitative and quantitative compositional mapping
- Week 8: (Nov. 2): Goldstein Chapter 30, Instructor notes: Focused Ion Beam Microscopy
- Week 9: (Nov. 9): Catch-up, Q&A
- Week 10 (Nov. 16): – Goldstein Chapter 29: EBSD
- Week 11 (Nov. 23): Sample preparation
- Week 12 (Nov. 30): Guest lecture – Dr. Brian Langelier – Atom Probe Tomography
- Week 13 (Dec 7, 10, 14): Class presentations
- Final Exam (To be arranged)

Links are Provided for the Following Previously Filmed Demonstrations:

1) An introduction to the SEM

2) An introduction to sample preparation (1 hour Materials, 1 hour Bio)

3) Introduction to EDS analysis

4) LVSEM (6610), Ultrahigh resolution SEM, Low-voltage EDS (Magellan)

5) Introduction to Focused Ion Beam

6) FIB applications (done on PFIB)

7) Introduction to Image Analysis.

8) EBSD/TKD analysis

9) A tour of atom probe.

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.

Authenticity / plagiarism detection

This course will use a web-based service (Turnitin.com) to reveal authenticity and ownership of student submitted work. For courses using such software, students will be expected to submit their work electronically either directly to Turnitin.com or via an online learning platform (e.g. A2L, etc.) using plagiarism detection (a service supported by Turnitin.com) so it can be checked for academic dishonesty.

Students who do not wish their work to be submitted through the plagiarism detection software must inform the Instructor before the assignment is due. No penalty will be assigned to a student who does not submit work to the plagiarism detection software. **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.