

## **EMA6507: Scanning Electron Microscopy**

Summer C 2016

3 Credits

Classroom location: CSE E107

Meeting times: Tuesday, period 3 (11:00 a.m. – 12:15 p.m.)  
Thursday, periods 3 and 4 (11:00 a.m. – 1:45 p.m.)

### **I. Instructor information**

Dr. Nicholas G. Rudawski

Office location: 203 Nanoscale Research Facility (building #0070)

Office phone: (352) 392-3077

E-mail: [ngr@ufl.edu](mailto:ngr@ufl.edu) (preferred contact method)

Office hours: by appointment only (please do not come to my office unannounced)

Class website: run through e-learning in canvas at <https://lss.at.ufl.edu/>

### **II. Course description and objectives**

This course provides an introduction and overview of scanning electron microscopy (SEM) as emphasized for materials scientists and those studying the physical sciences with emphasis placed mainly on analysis of inorganic materials (metals, semiconductors, and ceramics). This course also will provide students with a theoretical background required prior to training on the SEMs at the Major Analytical Instrumentation Center (MAIC); successful completion of this course completes the basic prerequisite necessary to start training on the SEMs at MAIC. By the end of the course, students will be able to understand the following:

Microscopy basics

Considerations of electromagnetic lenses

Construction and modes of operation of an SEM

Fundamentals of electron-solid interactions

The SEM image formation process

High-resolution SEM imaging

Specimen coatings and contamination

SEM for qualitative and quantitative chemical analysis (EDS, WDS, AEG)

Stereomicroscopy

Environmental (low-vacuum) SEM

Electron backscatter diffraction analysis

Construction and operation of a focused ion beam system

Fundamentals of ion-solid interactions

### **III. Recommended textbooks**

1. "Scanning electron microscopy and X-ray microanalysis" by Goldstein *et al.*; third edition (ISBN: 978-1-4613-4969-3)

[link.springer.com/book/10.1007%2F978-1-4615-0215-9](http://link.springer.com/book/10.1007%2F978-1-4615-0215-9)

2. "Introduction to focused ion beams" by Giannuzzi and Stevie; (ISBN: 978-0-387-23116-7)

[link.springer.com/book/10.1007%2Fb101190](http://link.springer.com/book/10.1007%2Fb101190)

Digital as well as hard copy versions of Goldstein *et al.* can be purchased for a nominal fee when the orders are placed online while using the UF network. Giannuzzi and Stevie may be accessed online, free of charge at the link listed above (or hard copies may again be purchased for a nominal fee while using the UF network). If you plan on doing a lot of SEM work, I would strongly recommend investing in a copy of Goldstein *et al.* as this is an excellent SEM reference text. Likewise, if you plan on doing a lot of FIB work, I would also recommend investing in a copy of Giannuzzi and Stevie for the same reason.

#### IV. Course outline

##### A. Tentative course schedule and suggested reading (subject to change)

Date	Topic(s)	Suggested reading
05/10/16	Introduction; microscopy basics; electrons for microscopy; SEM history, advantages/disadvantages/capabilities, basic electron-sample interactions, probe parameters	Goldstein: 1 (entire); 2.1.2
05/12/16	Ray diagrams; perfect convex lens basics, focusing, angles, diffraction contribution to probe size, depth of field	Goldstein: 2.3.1.2; 2.3.3; 2.3.5.2; 4.2.6
05/17/16	Magnetic lenses; lens defects; condenser and objective lenses; spherical and chromatic aberration, astigmatism; defect contributions to probe size	Goldstein: 2.3.1.1; 2.3.2; 2.3.5
05/19/16	Construction of a basic SEM; non-lens SEM components, the SEM vacuum system (differential pumping)	Goldstein: 2.1.1
05/24/16	SEM gun types; gun brightness; gun and probe current contributions to probe size; ultimate probe size (all factors considered)	Goldstein: 2.2; 2.3.4; 2.4
05/26/16	Open Q&A for Exam 1; Electron interaction volume and range; generation of secondary and backscattered electrons	Goldstein: 3 (entire)
05/31/16	<b>Mid-term exam 1</b>	N/A
06/02/16	The image formation process; imaging distortions detectors used for collecting secondary and backscattered electrons	Goldstein: 4.1 – 4.2.7; 4.3
06/07/16	Concept of contrast; atomic number, crystallographic, and topographical contrast in SEM images; image	Goldstein: 4.4 – 4.6; 5.7.3

	processing	
06/09/16	High resolution SEM imaging; immersion and deceleration operating modes	Goldstein: 5.1; additional material
06/14/16	SEM sample preparation; use of coatings; contamination issues and reduction	Goldstein: 11 (entire); 15 (entire)
06/16/16	Environmental (low vacuum) SEM for non-conductive and biological specimens	Goldstein: 5.6
06/28/16	Stereomicroscopy in SEM	Goldstein: 5.5
06/30/16	Open Q&A for Exam 2; Overview of analytical electron microscopy techniques; qualitative versus quantitative analytical electron microscopy	N/A
07/05/16	<b>Mid-term exam 2</b>	N/A
07/07/16	Generation of X-rays; ionization cross-section; fluorescence yield; absorption; EDS system construction; SEM settings for EDS; qualitative EDS (identification of peaks)	Goldstein: 6 (entire); 7.1; 7.2; 7.5.2; 8 (entire)
07/12/16	Quantitative EDS of flat specimens (atomic number, absorption, and fluorescence corrections); considerations for non-flat specimens	Goldstein: 9 (entire); 10.3; 10.4
07/14/16	Wavelength dispersive spectroscopy; WDS system construction; advantages/disadvantages compared to EDS; X-ray mapping; light element analysis	Goldstein: 7.3; 10.6; 10.7; 10.8
07/19/16	Auger electron spectroscopy; advantages/disadvantages compared to EDS/WDS; open Q&A for exam 3	Goldstein: 6.2.2
07/21/16	<b>Mid-term exam 3</b>	N/A
07/26/16	Backscattered electron diffraction	Goldstein: 5.8
07/28/16	Focused ion beams; fundamentals of ion-solid interactions; applications	Giannuzzi: 1 (entire); 2 (entire); 12 (entire)
08/02/16	Open Q&A for Exam 4; time allotted to cover any remaining material	TBD
08/04/16	<b>Final exam</b>	N/A

## B. Suggested reading

Suggested reading from both textbooks for each class is specified in the above tentative schedule (subject to change). It is not necessary to complete the suggested reading to successfully complete this course, but I do feel that the suggested reading provides a valuable counterpart to the lectures and certainly cannot hurt.

## C. List of assessments

1. Three (3) in-class mid-term exams (22% of final score for each mid-term exam)

Each mid-term exam will consist of 20 equally weighted multiple choice questions and will not be explicitly cumulative in nature; the use of a multiple choice format is to remove the ambiguity and fairness issues that tend to accompany the grading of essay/extended answer questions.

Tentative mid-term exam dates: 05/31, 07/05, and 07/21

2. Final exam (34% of final grade)

The final exam will consist of 30 equally weighted multiple-choice questions and will be explicitly cumulative in nature; it will be given in class on 08/04 (last day of class).

3. Three (3) in-class, unannounced extra credit quizzes

Each quiz will consist of 10 equally weighted true/false question; again, the use of a true/false format here is for reasons similar to those outlined regarding the exams. The first quiz will be given between the drop/add deadline and the first mid-term exam, the second quiz between the first and second mid-term exams, and the third quiz between the second and third mid-term exams. The unannounced quizzes will start promptly at the beginning of class; if you arrive more than 5 min late, you will not be allowed to take the quiz (EDGE students will also be allowed to take these quizzes, but will not be subjected to any such constraints and will have flexible return deadlines). The quizzes provide an opportunity to earn bonus credit on the exams and to give you an incentive to attend class and actively study the material. You must get at least 7 questions right to pass an extra credit quiz; passing an extra credit quiz with a score of 7 or 8 (9 or 10) correct questions will result in you receiving 1 (2) bonus points on the upcoming mid-term exam.

#### **D. Make-up assessments policy**

In general, make-ups for missed exams will not be given except in cases of illness or planned attendance of academic-related functions (research conferences, etc.). If you claim you could not be present to take an exam due to illness, you may take the exam at a later date provided you produce a doctor's note verifying your need to be absent. You have until 12:00 PM on the last day of the drop/add period (05/10/16) to inform me of any planned absences due to academic-related functions so that I may accommodate you accordingly. Absences for reasons not related to illness or planned attendance of academic-related functions (e.g., missing class to go on vacation), will generally not be accommodated. No make-ups will be given for missed extra credit quizzes for any reasons. Of course, if you are an EDGE student, you will be given additional flexibility with the scheduling and returning of your assessments.

#### **V. Attendance and classroom conduct**

Attendance is not required, and based on my experience over the past several years of teaching I am forced to begrudgingly conclude that regular attendance may not even be

necessary to perform well in any course. However, you will have to attend class regularly if you want to take advantage of the extra credit opportunity via the unannounced quizzes and you must be present to take the exams. During class, please be respectful and pay attention; silence/put away your cell phones; please do not bring and read newspapers; you may bring in your laptop computers to take digital notes, but please do not use your computers for leisurely activities (aimlessly surfing the internet, accessing social networking sites, playing games, etc.). As the instructor, I reserve the right to have anyone removed from the classroom that is acting disrespectfully and/or disruptively.

## **VI. Grading procedure**

At the end of the term, students will be ranked in terms of final scores. Different letter grades will be assigned to distinct groupings of scores (i.e., the top group will receive A and A- grades, the next group will receive B+ through B- grades, etc.); thus, you are effectively been graded relative to the performance of the rest of the students in the case. There is no predetermined or preset scale for grading, but I will give a projected final grade for everyone after each exam. Greater information on current UF policies for assigning grade points may be found at: <http://gradcatalog.ufl.edu/>.

## **VII. Academic misconduct**

Academic misconduct (cheating, plagiarism, etc.) is a very serious matter and will not be tolerated in any capacity; all students are required to abide by the Student Honor Code as described in detail at:

<https://www.dso.ufl.edu/sccr/process/student-conduct-honor-code/>

**It is the responsibility of you, the students, to understand what does and does not constitute a violation of the student honor code.** If I believe any student is violating the student honor code, it will be reported immediately to academic services in the MSE department, fully investigated, and (if necessary) properly sanctioned.

## **VIII. Accommodations for students with disabilities**

Students requesting classroom accommodation must first register with the Dean of Students Office. The Dean of Students Office will provide documentation to the student who must then provide this documentation to the instructor when requesting accommodation.