ENMA 441 / ENMA641
Characterization of Materials
Fall 2019 Syllabus

This course covers techniques to characterize the structure and properties of materials whose characteristic dimensions range from nanometers to macroscopic. These include crystalline and noncrystalline materials, with a special attention to materials of current technological interest. The course will include guest lectures from experts and laboratory demos of a number of important techniques.

Course Goal
Students learn the basics of scanned probe microscopy, electron microscopy and x-ray scattering techniques for characterization of materials at the nm scale.

Instructor

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Teaching Assistant:

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Topics

Lectures:
Light Microscopy & Resolution
Scattering & Small Angle X-Ray Scattering (SAXS)
X-Ray Diffraction (XRD)
Transmission Electron Microscopy (TEM)
Scanning Electron Microscopy & X-Ray Elemental Analysis (SEM/EDS)
X-Ray Photoelectron Spectroscopy (XPS)
Scanned Probe Microscopies
- Scanning Tunneling Microscopy
- Atomic Force Microscopy (AFM)

Secondary Ion Mass Spectroscopy
Optical spectroscopy
Thermal Characterization

Lab Demos:
SAXS, XRD, TEM, SEM/EDS, XPS, AFM, Thermal Characterization (tentative)

Class Times and Place
Class will be held Tuesday/Thursday from 12:30 pm-1:45 pm. Lectures will be held in CHE2136. Laboratories will be performed at AIMLab, MEMIL and the Chemistry Department's Surface Analysis/XRay Center.

Textbook:
"Materials Characterization: Introduction to Microscopic and Spectroscopic Methods", 2nd ed., Yang Leng (Wiley-VCH, New York, 2013)

Recommended:
"Methods of X-Ray and Neutron Scattering in Polymer Science", 2nd ed., ed. Ryong-Joon Roe (Oxford University Press, Oxford, 2000)
"Scanning Probe Microscopy and Spectroscopy: Theory Techniques and Applications", 2nd ed., ed. Dawn Bonnell (Wiley-VCH, New York, 2001)

Recommended Review Articles

SAXS: "Small-Angle X-Ray Scattering on Biological Macromolecules and Nanocomposites in Solution", Clement E. Blanchet and Dmitri I. Svergun, *Ann. Rev. Phys. Chem* **64**, 37 (2013); "Small Angle X-Ray Scattering Technique", K. L. Yudowitch, *Rev. Sci. Instrum*. **23**, 83 (1952); "Introduction to Small-Angle Neutron Scattering and Neutron Reflectometry", Andrew J Jackson, NIST Center for Neutron Research (May 2008)
TEM: "Transmission Electron Microscopy of Shape-Controlled Nanocrystals and Their Assemblies", Z. L. Wang, *J. Phys. Chem. B* **104**, 1153 (2000); "Materials Characterization In The Aberration-Corrected Scanning Transmission Electron Microscope", M. Varela, A.R. Lupini, K.van Benthem, A.Y. Borisevich, M.F. Chisholm, N. Shibata, E. Abe, and S.J. Pennycook, *Annu. Rev. Mater. Res.* **35**, 539 (2005);
STM: "Scanning Tunneling Microscopy", J. E. Griffiths, *Ann. Rev. Mater. Sci.* **20**, 219 (1990); "Scanning tunneling microscope instrumentation", Y. Kuk and P. J. Silverman, *Rev. Sci. Instrum*. **60**, 165 (1989); "Functional and Spectroscopic Measurements with Scanning Tunneling Microscopy", A. M. Moore and P. S.Weiss, *Annu. Rev. Anal. Chem*. **1**, 857(2008)
AFM: "Advances in atomic force microscopy", Franz J. Giessibl, *Reviews of Modern Physics* **75**, 949 (2003); "A review of atomic force microscopy imaging systems: application to molecular metrology and biological sciences", N. Jalili, K. Laxminarayana, *Mechatronics* **14** 907 (2004); "Atomic force microscopy as a multifunctional molecular toolbox in nanobiotechnology", D. J. Müller and Yves F. Dufrêne, *Nature Nanotechnology* **3**, 291 (2008); "Force measurements with the atomic force microscope: Technique, interpretation and applications", H.-J. Butt, B. Cappella, M. Kappl, *Surf. Sci. Rep*. **59**, 1–152 (2005)

Suggested References (Books):

Quantum Mechanics: Any good textbook on quantum mechanics. The physics department is using "Introduction to Quantum Mechanics", D. J. Griffiths, (Prentice-Hall, New York, 1994). An easy to read and understand book is "Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particle", R. Eisberg and R. Resnick (Wiley, New York, 1974). Another good choice, at a more advanced level is "Quantum Mechanics," vol. 1, C. Cohen-Tannoudji (Wiley, New York, 1977).
Solid State Physics: "Introduction to Solid State Physics," 7th ed., C. Kittel, (Wiley, New

York, 1996). **Forces:** "Intermolecular and Surface Forces," 2nd ed., J. Israelachvili, (Academic Press, London, 1992).
SEM: "Scanning Electron Microscopy and X-Ray Microanalysis", 2nd Ed., J.I. Goldstein, D.E. Newbury, P. Echlin, D.C. Joy, A.D. Romig, C. E. Lyman, C. Fiori and E. Lifshin, (Plenum, New York 1992)
TEM: "Transmission Electron Microscopy," David Williams and C.Barry Carter, (Plenum Press, New York and London, 1996)
Diffraction: "Diffraction Physics," 3rd ed., J. Cowley (North Holland, Amsterdam, 1995).

Approach
The course is taught following the text, from lecture notes and readings from the current literature. It includes lab demos in which measurements are observed and images/data are analyzed.

Course Objectives
This course is intended to introduce a number of techniques used to characterize materials including structure at length scales from atoms to macroscopic dimensions, composition, electronic structure, as well optical, electric, magnetic and transport properties. The emphasis is on what each technique measures, how the measurements can be interpreted, and what the limits are to the information which can be obtained.
Students taking this course learn:
1. Scattering phenomena and their application to characterizing materials.
2. Microscopy and image formation with light and charge particles, like electrons.
3. About surface forces and potentials, and how these are used in scanning force microscopy and force curve interpretation.
4. Elements of quantum mechanical confinement and tunneling, and how these are used in scanning tunneling microscopy and spectroscopy.
5. To analyze research results critically and to communicate the analysis effectively.

Course Documents
Course documents, including assignments will be posted on https://elms.umd.edu/

Grading Method (441)
Homework Assignments 30%
Data Analysis Reports 30%
Attendance & Participation 10%

Grading Method (641)
Homework Assignments 20%
Data Analysis Reports 20%
Final Term Paper 20%
Attendance & Participation 10%

Both 441 & 641: Final exam on Monday, December 16 1:30-3:30pm 30%

You are expected to submit a report for each the demos even if you are not present during the demo. The questions to be answered for every demo are on ELMS.

Assignment Submission Expectations
All assignments are expected to be submitted online in valid PDF format unless otherwise specified or permitted in advance. Numerous resources are available for creating, editing, and checking PDF files. Please see the tutorial document on ELMS.

Academic Integrity
The University of Maryland, College Park has a nationally recognized Code of Academic Integrity. This Code sets standards for academic integrity at Maryland for all undergraduate and graduate students. As a student you are responsible for upholding these standards for this course. It is very important for you to be aware of the consequences of cheating, fabrication, facilitation, and plagiarism. You are expected to review the code of academic integrity at http://www.president.umd.edu/policies/iii100a.html and the student honor council at http://www.shc.umd.edu/

CourseEvalUM
Your participation in the evaluation of courses through CourseEvalUM is a responsibility you hold as a student member of our academic community. Your feedback is confidential and important to the improvement of teaching and learning at the University as well as to the tenure and promotion process. CourseEvalUM will be open for you to complete your evaluations for semester courses sometime in December 2018. Please go directly to the website (www.courseevalum.umd.edu) to complete your evaluations. By completing all of your evaluations each semester, you will have the privilege of accessing online, at Testudo, the evaluation reports for the thousands of courses for which 70% or more students submitted their evaluations.

Counseling Center/Learning Assistance Service
"If you are experiencing difficulties in keeping up with the academic demands of this course, contact the Learning Assistance Service, 2202 Shoemaker Building, 301-314-7693. Their educational counselors can help with time management, reading, math learning skills, note-taking and exam preparation skills. All their services are free to UM students." http://www.counseling.umd.edu/

Policies relevant to Undergraduate Courses
The website at http://ugst.umd.edu/courserelatedpolicies.html covers topics that are addressed in the various policies including academic integrity, student rights, student and instructor misconduct, accessibility and accommodations, attendance and excused absences, grades and appeals, copyright and intellectual property.