ME 619
ME/MtSE 619
Title: Nano-scale Characterization of Materials

Prerequisites: Graduate standing, knowledge of basic principles of physics, mathematics, materials science, and engineering

Reason for prerequisites: Understanding of nanotechnology and operation of advanced analytical instrumentation requires proper knowledge of basic principles of physics, mathematics, materials science, and engineering

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Weekly listing of topics (15-week schedule)

Week	Lecture, Lab, Seminar
1	Introduction
2-4	Atomic Force Microscopy
5-6	Dielectric Spectroscopy
7-8	Near-Field Scanning Optical Microscopy
9-11	Light Scattering in Particle Characterization Instrumentation
12	Project Presentations
13	Basics of Electron Microscopy
13-14	Specimen Interaction with an Incident Electron Beam
15	Final Exam

Course description

Nanostructures are the smallest human-made objects exhibiting novel physical, chemical, and biological properties. The emerging field of nanoscience and nanotechnology is leading to a technological revolution in the 21st millennium. In contrast to conventional technologies, nanotechnologies operate on molecular levels to create and utilize materials, devices, and systems with fundamentally new molecular organization. The course introduces students to the concepts and principles of nanotechnology and advanced instrumentation for the characterization of materials and structures at nanoscale. Work at the W.M. Keck Foundation Laboratory will provide students with hands-on ability to operate advanced analytical instrumentation, run computer software, and perform measurements. The students will learn how to work as a team by cooperating in a group to carry out a short research project on specific applications of nanotechnology, conduct laboratory work, and prepare written reports & verbal presentations at the seminar.

Combining (25%) lectures, (15%) seminars, and (60%) laboratory work, the course will provide students with

- Understanding, characterization, and measurements of nanostructure properties
- Ability for synthesis, processing, and manufacturing of nanosystems
- Ability to communicate effectively the knowledge of nanotechnology and advanced instrumentation

Course objectives

- Major differences between the behaviors of macro- and nano-scale systems
- Hands-on introduction to advanced instrumentation for the manipulation of materials and structures at the nanoscale level
- Preparing students to conduct research and development of nanodevices
- Insight in the societal and economic impacts of nanotechnology

Course outline

▪ Introduction	Basic principles of nanotechnology Major differences between the behaviors of macro- and nanoscale systems Deep roots for nanotechnology A brief history of nanotechnology Nanomanipulation and investigative tools
▪ Atomic Force Microscopy (AFM)	Concepts of scanning probe microscopy Contact and non-contact AFM Piezoelectric scanners Feedback control system Force modulation microscopy Phase detection microscopy Electric and magnetic modes of AFM Evaluation of AFM measurements
▪ Dielectric Spectroscopy	Polarization mechanisms Dielectric measurements Evaluation of dielectric measurements Applications of impedance sensors
▪ Near-Field Scanning Optical Microscopy (NSOM)	Microscopic imaging and resolution Illumination and collection modes NSOM configurations Scanning process NSOM taper optics NSOM imaging theory NSOM instrumentation
▪ Light Scattering in Particle Characterization Instrumentation	Mechanisms of light scattering Angular patterns of scattered intensity Polarization of scattered light Dynamic light scattering Methods of particle size determination
▪ Basics of Electron Microscopy	Diffraction limit Transmission Electron Microscopy (TEM) TEM basics Scanning Electron Microscopy (SEM) SEM basics
▪ Specimen Interaction with an Incident Electron Beam	Bulk specimen interactions: Backscattered electrons, Secondary electrons, Auger electrons, X-rays Thin specimen interactions: Unscattered

electrons, Elastically scattered electrons, Inelastically scattered electrons
Energy-filtered Transmission Electron Microscopy
Energy Dispersive X-Ray Spectroscopy

References

- Lecture hands-outs and laboratory manuals of Atomic Force Microscope, Near-Field Optic Microscope, Dielectric Spectrometer, Particle Counters, and Electron Microscope.
- Nanotechnology Research Directions: IWGN Workshop Report Vision for Nanotechnology in the Next Decade, edited by M.C. Roco, R.S. Williams, and P. Alivisatos, Kluwer Academic Publishers, 2000 http://www.nano.gov/
- Nanostructure Science and Technology: R & D Status and Trends in Nanoparticles, Nanostructured Materials and Nanodevices, edited by R.W. Siegel, E. Hu, and M.C. Roco, Kluwer Academic Publishers, 1999
- K. Eric Drexler, The Coming Era of Nanotechnology and other educational sources, on-line http://www.foresight.org/EOC/index.html; http://www.foresight.org/nano/index.html
- S.D. Senturia, Microsystem Design, Kluwer Academic Publishers, 2001
- M.A. Paesler and P.J. Moyer, Near-Field Optics Theory: Instrumentation, and Applications, Wiley & Sons, 1996
- R. Xu, Particle Characterization: Light Scattering Methods, Kluwer Academic Publishers, 2000
- The MEMS Handbook, edited by M. Gad-el-Hak, CRC Press, 2002

Laboratory work

Labs will be conducted at the W.M. Keck Foundation Laboratory, York Center for Environmental Engineering and Science, Room 303

A missed lab will be averaged into the final grade as *zero*, unless an excuse is obtained. Excuses are granted only for very serious circumstances attested to by the NJIT administration, verifiable and significant medical problems, religious holidays, and also serious personal situations, such as deaths in the family. A student who has been excused will be required to take a makeup lab.

Project assignment

Suggested topics for research projects include but are not limited to:

- Synthesis and processing of nanostructures
- Nanophase ceramics, polymers, and composites
- Dispersions, coatings, and powders of nanoparticulates
- Nanotechnology in tissue engineering
- Nanofabricated structures and devices in biomedical engineering
- Nanotechnology in energy and chemicals industries
- Nanoscale processes in the environmental technologies

Project grading

Peer evaluation of an oral presentation by the seminar participants will include

- Mastery of the subject
- Presentation of the subject matter
- Preparation for the seminar
- Capture of the audience's attention

Assessment criteria and grading

This course has been designed so that lectures, seminars, project assignments, and laboratory work are integral and essential parts of the learning process. Final grades will be determined from scores as follows:

- Project, written report and oral presentation 50%

- Laboratory, written reports and oral presentations 30%
- Final exam 20%

The final grade will be assigned on the basis of "*a curve*".