Graduate Certificate Program in "Nanomaterials"

MATERIAL SCIENCE AND ENGINEERING

Nanotechnology and nanomaterials are becoming important in a wide range of industries. This four-course certificate program will stress two key areas:

(1) nanocharacterization methods and

(2) the differences between nanomaterials and bulk materials of the same composition. Examples will be shown of nanometer-sized technological structures related to electronics, photonics, catalysis, and biotechnology.

Credits earned towards a certificate may be accepted as part of a master's or Ph.D. degree program in materials science and engineering. A proposed master's program in nanomaterials is currently being developed.

Rationale:

This certificate program will enable students to gain a working knowledge of a broad range of instrumentation for solving nanotechnology problems. In addition, this program will highlight the effect of size on physical properties.

Admission Criteria:

B.S. degree in chemistry, physics, or any branch of engineering
Undergraduate GPA: 3.00 or higher
Undergraduate chemistry, physics, and mathematics through differential equations and linear algebra
Pre-requisite: An introductory materials course similar to Lehigh's Mat 33
Admission policies will be the same as for other graduate students in materials science and engineering
TOEFL score > 550
The application process would be similar to other interdisciplinary graduate programs. Eventually several departments may participate, but the program would begin in the Dept. of Materials Science and Engr.

Certificate Program Requirements:

- Two core courses to give a common background in materials and nanotechnology

- Two elective courses from a list provided

Requirements for Completion of Certificate:

Completion of at least 12 credits
Not more than one grade below B-
All other university requirements apply, such as deadlines and fees
All work must be completed in 3 years

Transferability:

Credits earned towards a certificate may be accepted as part of a master's or Ph.D. degree program in materials science and engineering
Normal time limits for completion of an advanced degree program apply (i.e., a total of 6 years for the master's or 10 years for the doctorate) beginning with the date of enrollment in the certificate program

Core Courses:

<u>Materials for Nanotechnology (3)</u>
(Mat 398/498)
This course, offered on both an undergraduate and a graduate level, begins with an introduction to the nanoworld and how we see the nanoworld through transmission electron microscopy. Other topics include: probing nanosurfaces, carbon as a nanomaterial, fullerenes, carbon nanotubes, metal clusters, metal nanoparticle preparation, and directed self-assembly of nanoparticles. Also discussed are the thermal, chemical, electronic, optical, and magnetic properties of metal nanoparticles, nanowires, semiconductor nanoparticles, and inorganic nanoparticles.

<u>Strategies for Nanocharacterization (3)</u>
(Mat 397/497)
Lectures describe various nanocharacterization techniques in terms of which technique is best for specific measurements. Special attention paid to spatial resolution and detection limits for SEM, TEM, X-ray analysis, diffraction analysis, ion beam techniques, surface techniques, AFM and other SPMs, and light microscopies and spectroscopies.

Current Elective Courses

<u>Thin Film Processing And Mechanical Behavior (3)</u>
(Mat 397)
Metallic, ceramic and glassy films, with thickness less than approximately 1 μm, formed by gas phase deposition. Thin film applications, vacuum fundamentals, PVD and CVD, models for general thin film growth, epitaxial growth, sources of stress, deformation mechanisms, and mechanical characterization techniques such as substrate curvature and nanoindentation. Prerequisite: Mat33. Also recommended, but not required, is some experience with mechanics of materials.

<u>Electron Microscopy and Microanalysis (4)</u>
(Mat 334)

Fundamentals and experimental methods in electron optical techniques including scanning electron microscopy (SEM), conventional transmission (TEM) and scanning transmission (STEM) electron microscopy. Specific topics covered will include electron optics, electron beam interactions with solids, electron diffraction and chemical microanalysis. Applications to the study of the structure of materials are given. Prerequisite: consent of the department chair.

Crystallography and Diffraction (3)
(Mat 333)
Introduction to crystal symmetry, point groups, and space groups. Emphasis on materials characterization by x-ray diffraction and electron diffraction. Specific topics include crystallographic notation, stereographic projections, orientation of single crystals, textures, phase identification, quantitative analysis, stress measurement, electron diffraction, ring and spot patterns, convergent beam electron diffraction (CBED), and space group determination. Applications in mineralogy, metallurgy, ceramics, microelectronics, polymers, and catalysts. Lectures and laboratory work.

Advanced Transmission Electron Microscopy (4)
(Mat 423)
The theory and practice of operation of the transmission and scanning transmission electron microscope. Techniques covered include bright field, high resolution and weak-beam dark field, lattice imaging, diffraction pattern indexing and Kikuchi line analysis. The theory of diffraction contrast is applied to the interpretation of electron micrographs. Specimen preparation techniques. Prerequisite: Mat 334 or equivalent.

Advanced Scanning Electron Microscopy (4)
(Mat 427)
The theory and practice of operation of the scanning electron microscope and electron microprobe. Techniques covered will include high-resolution scanning, quantitative electron probe microanalysis. Electron beam sample interactions. X-ray spectrometry and electron optics will be discussed in detail. Prerequisite: Mat 334 or equivalent.