Materials Science and Engineering (ESM)

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Degrees awarded: M.S. in Materials Science and Engineering; Ph.D. in Materials Science and Engineering

The Department of Materials Science and Engineering offers graduate work leading to the Master of Science and Doctor of Philosophy degrees. The motivating philosophy of the graduate program is to provide the student with a broad synthesis of the theoretical and experimental techniques required to work with all classes of materials. Emphasis is placed on courses that unify the field in terms of fundamentals treated with sufficient depth to enable the student to make technological contributions in diverse areas of materials science and engineering. Laboratory and coursework are structured to provide programs for students who (1) are entering intensive basic research-oriented programs leading to Ph.D. or Master of Science degrees, (2) are currently employed and can complete their studies in the evening, or (3) are working in materials-related industries and can integrate their work experience into their degree requirements.

Industrial Cooperative Ph.D. Program

A special extramural Ph.D. degree program is offered by the Department of Materials Science and Engineering for highly qualified individuals working in an industrial materials research area. Candidates for this program must have met the graduate coursework requirements for the Ph.D. typically by earning a master's degree. Doctoral research is generally done at the student's place of employment, rather than on the University campus. Contact the Department for further information.

One-Year Master's Degree Program

Students admitted to this program can complete all requirements for the degree in two semesters of full-time study. Required courses are given in the late afternoon or evening and research projects can be carried out at the student's work location. Contact the Department for further information.

Bachelor of Science Degree/ Master of Science Degree Program

An engineering science, engineering chemistry, or physics student may apply at the end of the junior year for admission to this special program, which leads to a Bachelor of Engineering or Bachelor of Science degree at the end of the fourth year and a Master of Science degree at the end of the fifth year. In the senior year, a student in the program takes six credits of graduate courses. In the fifth year, the student takes 24 credits, of which at least 18 credits are coursework and six credits are ESM 599 Research. The advantages of this program over the regular M.S. program is that a student may start his or her M.S. thesis in the senior year, and that he or she needs only 24 credits in the fifth year as opposed to 30 credits for a regular M.S. student. For details of the M.S. degree requirements, see the graduate program director.

Research Activities

Since its inception, the Department has had a strong research component, with a major emphasis in surface science and engineering. The Department has been successful in obtaining external funding for research and currently has the highest per capita faculty funding within the University. In 2003, the Department topped the list for research funding in the College of Engineering and Applied Sciences. The Department boasts more than $4 million in external funding for 15 total full-time faculty members. The Department hosts two main interdisciplinary centers, one on polymers and the other on thermal spray. These centers offer a unique and rich environment for interdisciplinary graduate research and education.

Garcia Center for Polymers at Engineered Interfaces: The Polymer Center offers an interdisciplinary program aimed at studying the molecular basis of macroscopic phenomena. With funds from industrial partners, the NSF and the Department of Energy (DOE), research is conducted on polymer dynamics, nanopatterning, thin film and interface engineering, surface modification, blends, polyelectrolytes, adhesion, block polymers, and wetting.

Center for Thermal Spray Research: The Center for Thermal Spray Research (CTSR) conducts both applied and fundamental research on thermal spray technology, which involves melt spray formation of protective coatings and free standing forms. CTSR is a unique facility containing a vast array of industrial-level plasma and combustion spray devices. In 1999, CTSR's research program received a significant boost through a $5 million award from the Defense Advanced Research Projects Agency (DARPA) to pursue revolutionary applications of thermal spray in electronics. Under the auspices of the Mesoscale Integrated Conformal Electronics initiative, CTSR has expanded its reach in the design, synthesis, and applications of thick film electronics and sensor materials. A new laboratory for both electronics fabrication and characterization has been set up.

Recent awards made to the faculty include two NSF Nanoscale Integrated Research Team awards (totaling $2 million), one concerning the use of metal oxide electronic noses for use as molecular and biological sensors, and the other concerning molecular electronics on the nanoscale.

The proximity to Brookhaven National Laboratory (BNL) and its advanced national facilities has been a major benefit to both faculty and students within the Department. Several faculty members hold guest appointments at BNL, while Brookhaven scientists participate in research and teaching within the Department. The DOE awarded the contract to manage BNL in 1998 to Brookhaven Science Associates, a consortium of other universities led by Stony Brook and the Battelle Memorial Institute. The University's relationship with this premier research facility greatly enhances both the Department's and Stony Brook's research programs.

At BNL, the facilities available to the

Department include particle accelerators for carrying out ion beam surface modification experiments and highly sophisticated surface analysis probes. The National Synchrotron Light Source (NSLS) is also located at BNL. As one of the participating research teams at NSLS, the Synchrotron Topography Research Group, centered in Stony Brook's Department of Materials Science and Engineering, is using special X-ray methods to image nondestructively dislocation microstructures. This enables image-detailed descriptions of dislocation motion and structures attendant to crystal growth and plastic deformation and fracture, as well as to interesting materials behaviors. The topographic method is also being used in Department-based studies of surface chemical reactivity. The Department recently was awarded a $1 million NSF Major Research Instrumentation grant to set up a center for crystal growth. The center is focused on developing capabilities for tackling the most challenging problems in crystal growth of novel advanced materials, and currently includes a high-pressure, high-temperature furnace for crystal growth of III-nitrides from solution-melts, a low-temperature CVD reactor for deposition of ZnO films, a two-zone high-temperature resistance-heater furnace for sublimation growth of ZnO, and a high-temperature RF reactor for SiC sublimation growth.

As a result of the University's Engineering 2000 initiative, our ties with industry are growing stronger: faculty members are working with industry on joint research projects and submitting cooperative proposals to outside agencies. The Department of Materials Science has led the effort in joint industry-University projects within the College of Engineering through the New York State Strategic Partnership for Industrial Resurgence (SPIR) program.

Stony Brook's own facilities include state-of-the-art low-energy electron diffraction (LEED); a state-of-the-art scanning electron microscope and a transmission electron microscope, both equipped with analytical capabilities and the latest software for electron diffraction simulation and image processing; an atomic force microscope; and electron spectroscopy for chemical analysis (ESCA) IAES/SIMS Infrared Microscopy units, as well as central characterization facilities that include equipment for microanalysis and X-ray techniques. A well-equipped materials fabrication and processing facility within the Department boasts a collection of furnaces capable of reaching 3,000ºC in controlled atmospheres or under vacuum, a resist-spinner, ellipsometer, contact angle goniometers, and a high-resolution Nomarsky metallurgical microscope with image processing capability.

The analytical electron facility of the Department consists of both scanning and transmission electron microscopes. The state-of-the-art Schottky Field Emission Scanning Electron Microscope (SEM) (LEO Gemini 1550) includes an In-Lens Secondary Electron Detector in addition to the standard E-T detector, and a Rutherford Backscatter Electron Detector. This SEM allows for high-resolution imaging of the surfaces and cross-sections of all types of solid materials. It is also fully equipped with an EDS (energy dispersive X-ray spectroscopy) system using an EDAX detector that provides elemental compositions and X-ray maps of the various phases of the materials examined. Finally, the SEM includes an Electron-Backscattered Electron Diffraction (EBED) analysis system based on the TSL/EDAX orientation imaging and Phase-ID software that allows for non-destructive diffraction analysis and orientation imaging (texture analysis) of the grain structure of the surface of the specimens tested.

This facility also includes a digitally controlled Transmission Electron Microscope (Philips CM12), complete with EDS and PEELS (Parallel-reading Electron Energy Loss Spectroscopy) facilities for detailed analytical studies. This tool allows for the direct observation of the "internal" structure of materials at resolutions as low as a few Å and for the determination of the crystal structure of their various components.

There are also facilities for sample preparation for electron microscopy and microanalysis observations, including precision ion milling units (such as VCR Group XLA 2000).

Furthermore, advanced software for electron diffraction patterns simulation and image processing is available (e.g., Desktop Microscopist and Digital Micrograph).

Another research area that is emerging in the Department includes the development and testing of chemical sensors. A gas sensor testing facility is being set up in the Department and it will be available shortly.

Other surface-related research involves studies of surface/environmental interactions. Using unique combinations of electron and ion spectroscopies, infrared and optical microspectroscopy and synchrontron-based techniques, research is being conducted into corrosion behavior and corrosion inhibition of engineering alloys, degradation of paints and other coatings, remediation of contaminated surfaces, and surface cleaning. Much of this work has included collaborations with other universities, industries, national laboratories, and government facilities such as the Army Research Laboratory, Weapons and Materials Directorate (Aberdeen, MD). An evolving area of collaborative research involves related studies of unique thin films and structures formed using femtosecond laster ablation. The structure of epitaxial surface monolayers is being studied using LEED; extension of this research is also performed at the NSLS. The preparation of thin films of magnetic metals is studied using ultrahigh-vacuum (UHV) molecular beam epitaxy (MBE) processing. These materials are used in the computer industry in disk storage devices. The magnetic properties of these materials are studied using a vibrating sample magnetometer (VSM) and magneto-optic Kerr effect (MOKE) spectroscopy. Research is also being performed on the chemical makeup of the newly discovered high-temperature superconductors. Novel methods of rapidly spraying such materials onto surfaces are being developed. Through a Department of Defense instrumentation program, a comprehensive thermal analysis and porosity laboratory has been set up within the Department.

Consistent with Stony Brook's designated mission as a research center, the cornerstone of the Department's academic program is the graduate work leading to the research-oriented M.S. and Ph.D. degrees. The Department has about 50 full-time, fully supported students and as many as 10 part-time students, most of whom work in Long Island's high-technology industries.

Admission

Admission is based on the graduate program committee's assessment of the applicant's aptitude for research and the compatibility of his or her interests with the active research programs and capabilities of the Department. Applicants are advised to pay particular attention to their statements of purpose (page 3 of the application form). Minimum requirements, in addition to those of the Graduate School, are as follows:

A. A bachelor's degree in engineering, mathematics, physics, chemistry, or a closely related area from an accredited college or university;

B. A minimum grade average of at least a B in all courses in engineering, mathematics, and science;

C. Results of the Graduate Record Examination (GRE) General Test;

D. For foreign students, results of the TOEFL exam with a score of at least 600 (paper), 250 (computer) or 90 iBT, and no subscore should be below a 22.

E. Acceptance by both the Department of Materials Science and Engineering and the Graduate School.

Faculty

Distinguished Professors

Chu, Benjamin, Ph.D., 1959, Cornell University: Structure and dynamics of supermolecular and polymeric systems, using laser-light scattering, fluorescence recovery after photo bleaching, transient electric birefringence, small-angle X-ray scattering with synchrotron radiation, and other spectroscopic techniques.

Herman, Herbert, Ph.D., 1961, Northwestern University: Protective coatings; thermal spray; composites; marine materials.

Professors

Clayton, Clive R., Ph.D., 1976, Surrey University, England: Environmental degradation of materials; XPS; AES; dynamic and static SIMS; electrochemical analysis synthesis by ultra-fast laser ablation; RHEED; protective coatings.

Dudley, Michael, *Chair,* Ph.D., 1982, University of Warwick, England: Synchrotron topography; crystal defects; mechanical properties.

Jona, Franco P., Ph.D., 1949, Swiss Polytechnic Institute (E.T.H.), Switzerland: Surface physics; LEED.

Mahajan, Devinder, Ph.D., 1979, University of British Columbia: Inorganic chemistry; fuel cells; catalysis.

Rafailovich, Miriam, Ph.D., 1980, Stony Brook University: Polymeric liquids; phase transitions; thin film wetting phenomena; atomic force microscopy; ion, X-ray, and neutron scattering.

Sampath, Sanjay, Ph.D., 1989, Stony Brook University: Thermal spraying; protective coatings; functioning graded materials; thick film electronics and sensors.

Seigle, Leslie, *Emeritus,* Ph.D., 1951, Massachusetts Institute of Technology: Thermodynamics of solids; diffusions in solids; protective coatings.

Sokolov, Jonathan C., Ph.D., 1983, Stony Brook University: Surface and interface properties of polymers and blends; phase transitions; neutron and X-ray scattering; EXAFS; SIMS.

Associate Professors

Charles Fortmann, Ph.D., 1985, Stanford University: Solid state physics; protein dynamics.

Gersappe, Dilip, *Graduate Program Director*, Ph.D., 1992, Northwestern University: Polymer theory and simulation.

Gouma, Pelagia-Irene (Perena), Ph.D., 1996, University of Birmingham, England: Advanced materials characterization; electron microscopy and microanalysis techniques; chemical sensors.

Halada, Gary, Ph.D., 1993, Stony Brook University: Electron spectroscopy; electrochemistry; surface engineering; optical spectroscopy; environmental remediation.

Assistant Professors

Koga, Tadadori, Ph.D., 1998, Kyushu University, Japan: Green nanofabrication of polymer thin films; chemical recycling of waste plastics and methane hydrate as a future energy resource.

Orlov, Alexander, Ph.D., 2005, University of Cambridge, U.K.; M.Phil., University of Cambridge, U.K.; M.S.E., University of Michigan; M.E./B.E., National Technical University, Ukraine: Materials for environmental applications; physical chemistry, environmental nanotechnology, and photocatalysis.

Pernodet, Nadine, Ph.D., 1996, Institut Charles Sadron, Strasbourg, France: Physical chemistry and polymers.

Venkatesh, T.A., Ph.D., 1998, Massachusetts Institute of Technology: Nanomaterials, smart materials, materials for MEMS and biomedical applications.

Research Professors

Gambino, Richard, M.S., 1976, Polytechnic Institute of New York: Magnetic thin films; magneto-optical properties; Hall effect and magneto-resistance of magnetic metals; epitaxial growth of magnetic materials.

Adjunct Faculty

Adzic, Radoslav, Ph.D., 1974, University of Belgrade: Surface electrochemistry; electrocatalysis; direct energy conversion; fuel cells.

Berndt, Christopher C, Ph.D., 1980, Monash University, Australia: Protective coatings; mechanical properties; biomaterials; thermal spray.

Chidambaran, Dev, Ph.D., 2003, Stony Brook University: Corrosion science and surface analysis.

Cooley, Lance, Ph.D., 1993, University of Wisconsin, Madison: Materials science.

Czajkowski, Carl, Ph.D., 1996, Stony Brook University: Nuclear materials engineering.

Dasgupta, Avijit, Ph.D., P.E., 1983, University of Miami: Environmental engineering.

Gu, Genda, Ph.D., 1989, Harbin Institute of Technology, Harbin, China: Materials science and engineering; single crystal characterization and physical properties measurement; single crystal growth and solidification of oxide materials and metallic materials.

Huang, Xianrong, Ph.D.,1995, Nanjing University, China: X-ray typography.

Isaacs, Hugh, Ph.D., 1963, Imperial College of Science and Technology, University of London, England: Electrochemical research.

Johnson, Peter, Ph.D., 1978, Warwick University, England: Physics.

Jones, Keith, Ph.D., 1955, University of Wisconsin, Madison: Physics.

Kondakis, Nicholas, Ph.D., 1989, Columbia University: High-energy physics.

Li, Qiang, 1991, Iowa State University at Ames: Energy and electronic materials; synthesis and characterization.

Lewis, Laura J.H., Ph.D., 1993, University of Texas, Austin: Materials science and engineering.

Russo, Lysa, M.S., 1992, Stony Brook University: Materials science.

Samuilov, Vladimir, Ph.D., 1986, Belarus State University: Physics.

Schwarz, Steven, Ph.D., 1980, Stanford University: Electrical engineering.

Stein, Richard, Ph.D., 1949, Princeton University: Physical chemistry.

Tobin, Al, Ph.D., 1968, Columbia University: Metallurgy.

Twiley, John, B.S., 1976, University of California, Riverside: Chemistry.

Weil, Edward, Ph.D., 1953, University of Illinois; Organic chemistry.

Welch, David O., Ph.D., 1964, University of Pennsylvania: Theoretical materials science; kinetics of diffusion; energetics; statistical mechanics; crystal lattice defects; equations of state phase equilibria; radiation effects.

Zaitsev, Vladimir, Ph.D., 1992, Moscow State University, Russia: Chemistry.

Zhu, Yimei, Ph.D., 1987, Nagoya University, Japan: Materials physics.

Degree Requirements

Requirements for the M.S. Degree

In addition to the minimum requirements of the Graduate School, the requirements for the M.S. degree in the Department of Materials Science and Engineering can be satisfied by either one of the two following options:

M.S. Non-Thesis Option

A. Election

The election of this option must be made by the student upon admission to the program and is considered a terminal degree.

B. Coursework

1. A minimum of 30 graduate credits with a grade point average of 3.0 or better in all graduate courses taken is required to graduate. All credits must be from coursework.

2. The 30 credits must include the following three core courses: ESM 511 Thermodynamics of Solids; ESM 513 Strength of Materials; and ESM 521 Diffusion in Solids. If the student does not receive a minimum of a B in a core course, he or she may repeat that course one other time.

3. In addition, all students who are supported as Teaching Assistants must complete ESM 501 Teaching and Mentoring Techniques and ESM 698 Practicum in Teaching.

4. Only six credits of ESM 696 Special Problems in Materials Science are allowed.

5. All courses taken outside the Department require permission from the graduate program director.

M.S. Thesis Option

A. Election

The election of this option must be made by the student upon admission to the program, and is normally considered part of the Ph.D. sequence. Students may not transfer to the non-thesis option while registered for a thesis master's or a Ph.D. degree.

B. Coursework

1. A minimum of 30 graduate credits is required to graduate; 24 credits must be from coursework. An average grade of B or better is required for all courses.

2. The 30 credits must include the following three core courses: ESM 511 Thermodynamics of Solids; ESM 513 Strength of Materials; and ESM 521 Diffusion in Solids. If the student does not receive a minimum of a B in a core course, he or she may repeat that course one other time.

3. In addition, all students who are supported as Teaching Assistants must complete ESM 501 Teaching and Mentoring Techniques and ESM 698 Practicum in Teaching.

4. The 30 credits must include six credits of ESM 599 Research.

5. Only six credits of ESM 696 Special Problems in Materials Science are allowed.

6. All courses taken outside the Department require permission from the graduate program director.

C. Thesis

For the student who elects to complete a thesis for the M.S. degree, the thesis must be approved by three faculty members, at least two of whom are members of the Department of Materials Science and Engineering, including the research advisor.

D. Final Recommendation

Upon fulfillment of the above requirements, the graduate program committee will recommend to the dean of the Graduate School that the Master of Science degree be conferred or will stipulate further requirements that the student must fulfill.

E. Transfer to Other Options

Transfer to another degree option in the Department can be made only with the written permission of the graduate program director.

Requirements for the Ph.D. Degree

A. Plan of Work

Before completion of one year of full-time residence, the student must have selected a research advisor who agrees to serve in that capacity. The student will then prepare a plan of further coursework. This must receive the approval of the student's advisor and of the graduate program committee.

B. Coursework

1. An average grade of B or higher is required for all courses.

2. A minimum of 24 graduate course credits is required to graduate (excluding ESM 599, 697, 698, and 699).

3. The 24 course credits must include the following three core courses: ESM 511 Thermodynamics of Solids; ESM 513 Strength of Materials; and ESM 521 Diffusion in Solids. If the student does not receive a minimum of a B in a core course, he or she may repeat that course one other time.

4. All students must complete ESM 501 Teaching and Mentoring Techniques.

5. The student must pass at least three credits of ESM 698 Practicum in Teaching and six credits of ESM 699 Dissertation Research on Campus.

6. Only six credits of ESM 696 Special Problems in Materials Science are allowed.

7. All courses taken outside the Department require permission from the graduate program director.

8. If a student is being supported the student must TA/GA/RA for five semesters.

C. Preliminary Examination

The preliminary examination must be taken before the beginning of the student's fifth semester. This is an oral examination designed to test the student's ability to utilize his or her materials science background to carry out research in a chosen field of study, and to make clear written and oral presentations of research. At least ten days prior to the examination, the candidate should submit a research proposal (10 to 15 pages) to the examiners that places the research in context and outlines a scenario for its completion.

The examination committee will consist of two Department of Materials Science and Engineering faculty members. If a second examination is required, it must be completed by the tenth week of the fifth semester.

D. Advancement to Candidacy

After the student has successfully completed all requirements for the degree, other than the dissertation, he or she is eligible to be recommended for advancement to candidacy. This status is conferred by the Dean of the Graduate School upon recommendation of the chair and the graduate program director.

E. Dissertation

The most important requirement of the Ph.D. degree is the completion of a dissertation, which must be an original scholarly investigation. The dissertation shall represent a significant contribution to the scientific literature, and its quality shall be compatible with the publication standards of appropriate and reputable scholarly journals. At least two semesters should elapse between the preliminary exam and submission of the dissertation.

F. Defense

The candidate shall defend the dissertation before an examining committee consisting of four members, including the research advisor, two members of the Department of Materials Science and Engineering, and one member from outside the Department.

G. Time Limit

All requirements for the Ph.D. degree must be completed within seven years after completing 24 credit hours of graduate courses in the program.

Courses

ESM 501 Teaching and Mentoring Techniques
Discussion of various phases of teaching, including preparation, classroom technique, and student evaluation. Also exploration of skills and understanding necessary for mentoring undergraduates and others involved in research.
Fall, 1 credit, S/U grading

ESM 502 Scanning Electron Microscopy Skills
Practical introduction to the operation of scanning electron microscopes, including energy-dispersive X-ray spectrometers. Required of all students who use the SEM in their research.
Spring, 1 credit, ABCF grading

ESM 503 Electron Diffraction
A quantitative discussion of electron diffraction as a means of micro-characterization of materials and as a basis for understanding image contrast in the transmission electron microscope. Topics covered include atomic, kinematical, and dynamical scattering; indexing diffraction patterns; and convergent-beam diffraction.
Spring, 3 credits, ABCF grading

ESM 511 Thermodynamics of Solids
Current knowledge regarding the thermodynamic properties of condensed phases is discussed. The thermodynamic treatment of ideal, regular, and real solutions is reviewed. Estimation of reaction-free energies and equilibria in condensed phase reactions such as diffusion, exication, and phase transformations; thermodynamic analysis of phase equilibrium diagrams.
Fall, 3 credits, ABCF grading

ESM 512 Structure of Materials
The structure of solids can be studied using X-ray, neutron, and electron diffraction techniques. Topics covered are coherent and incoherent scattering of radiation, structure of crystalline and amorphous solids, stereographic projection and crystal orientation determination, the concept of reciprocal vector space. Laboratory work in X-ray diffraction is also included.
Fall, 3 credits, ABCF grading

ESM 513 Strength of Materials
A unified approach for all solid materials will be used with regard to the correlation between microstructure and their macroscopic mechanical properties. The course deals with various testing techniques for delineating mechanical properties of materials, considering elasticity, inelasticity, plasticity, dislocation theory, cohesive strength, fracture, and surface wear. Attention is given to strengthening mechanisms for solids, metals, ceramics, and polymers.
Fall, 3 credits, ABCF grading

ESM 521 Diffusion in Solids
Kinetics and Transformations I changed to Diffusion in Solids. Atomistic rate processes in solids with emphasis on diffusion in crystals. Theory of diffusion and experimental techniques; the role played by a broad class of crystalline imperfections. Topics include annealing of deformed materials, kinetics of defect interactions, thermally controlled deformation, kinetics of nucleation and growth, solidification, and precipitation.
Fall, 3 credits, ABCF grading

ESM 522 Imperfections in Crystals
The characteristics of point defects in metals, semiconductors, and ionic solids are described, and the thermodynamics of point defects is developed. Dislocation theory is introduced and the structures of internal boundaries are described. Finally, interactions between lattice imperfections are discussed, with emphasis on plasticity and fracture.
Spring, 3 credits, ABCF grading

ESM 523 Solid-State Electronics
A study of the electronic processes in solids leading to the analysis and design of materials and devices. Crystal structures, binding, electrical and thermal conductivities, diffusion, galvomagnetic, thermomagnetic, and thermoelectric effects. Hall effect and magnetoresistance. Conductivity in thin films.
Fall, 3 credits, ABCF grading

ESM 531 Phase Transformations
Kinetics and Transformations II changed to Phase Transformations. A review of the processes by which structures are changed in the solid state. Classical nucleation theory including homogeneous and heterogeneous mechanisms. Diffusion and diffusionless growth mechanisms. Transformation kinetics.
Spring, 3 credits, ABCF grading

ESM 532 Materials Processing
A study of manufacturing processes used in the semiconductor industries. Topics include single crystal growth, compound formation, zone refining, epitaxial growth, doping techniques, thin film techniques, thick film techniques, passivations, isolations, lead bonding techniques, cleaning and etching, and failure analysis; discrete devices and integrated circuit devices; various modern concepts in IC processing.
Fall, 3 credits, ABCF grading

ESM 533 Polymeric Materials
Introduction to the physical properties of polymeric materials. Conformations, phase diagrams, and flow properties of polymers and polymer solutions. Rubber elasticity of polymer networks and melts. Flory-Huggins lattice model for concentrated solutions. Applications to diffusion, segregation, and spinodal decomposition in polymer blends. Experimental methods.
Fall, 3 credits, ABCF grading

ESM 534 Advanced Laboratory
Students perform a series of advanced materials experiments which involve some independent research. The results are then written in a report suitable for publication in a journal or proceeding.
Fall, 3 credits, ABCF grading

ESM 542 Modern Electron Microscopy
Principles and practice for transmission and scanning transmission electron microscopes. Instrument design. Specimen preparation. Instrument operation. Electron diffraction and imaging theory. Microanalysis using X-ray and electron spectra. Typical electron microscope investigations are outlined and used as examples.
Fall, 3 credits, ABCF grading

ESM 543 Engineering Ceramics
The characterization of ceramics is reviewed with special reference to advanced engineering ceramics, bulk high-temperature superconductors, and ceramic magnets. Typical microstructures and thermal, mechanical, and electrical properties are compared. These properties are related to the various methods of processing.
Spring 3 credits, ABCF grading

ESM 550 Introduction to Homeland Security
The course is a combination of lectures and laboratory experience to introduce students to critical issues and assess needs for homeland security. The course includes invited lectures by experts on special topics such as fundamentals of nuclear, chemical, and biological weapons and the associated threat to the transportation of goods and the public. The students will learn about cyber security, devices to safeguard materials from terrorist threats, safety of nuclear power plants and water supply, forensics, and emergency preparedness. The students will submit a term paper on a selected topic in lieu of the final exam.
Prerequisite: Undergraduate-level biology, chemistry, and physics
Fall, spring, 3 credits, ABCF grading

ESM 553 Nuclear Safeguards and Security
The course is intended to familiarize students with the fundamentals of nuclear physics, radiation, mining, weapons and fuel cycle, other than producing electricity, as it per-

tains to nuclear power plants. Topics include nuclear detection, devices to safeguard nuclear materials from terrorist threats, needed physical protection for safe handling and its relevance to Homeland Security. The course combines lectures with hands-on experience at the newly installed nuclear detection facility located at the nearby U.S. Department of Energy's Brookhaven National Laboratory.
Prerequisite: Undergraduate or equivalent physics and chemistry
Fall, spring, 4 credits, ABCF grading

ESM 554 Chemical and Biological Weapons: Safeguards and Security
This course deals with the fundamentals of chemistry and biochemistry related to chemical weapons (CW) and biological weapons (BW) that could be used by terrorists. Topics include CW and BW history, production, control, detection, identification, and emergency response measures to deal with intended or unintended release and escape, and security measures to protect and control stockpiles.
Prerequisite: Undergraduate or equivalent chemistry, biochemistry, and microbiology
Fall, spring, 4 credits, ABCF grading

ESM 555 Synchrotron Techniques in Materials Science
A short course in a selected synchrotron analytical technique as applied to problems in materials science. May include demonstration and hands-on experience at the National Synchrotron Light Source at Brookhaven National Laboratory, and synchrotron safety training.
Pre- or co-requisite: BNL Synchrotron Safety Training; students must complete BNL guest registration
1 credit, ABCF grading

ESM 560 Risk Assessment, Regulation, and Homeland Security
The course focus is on risk assessment associated with nuclear, chemical, and biological weapons as it relates to Homeland Security. Topics include air dispersion, uncertainty analysis, exposure measurements, epidemiology, toxicology, regulatory issues, risk management, risk communication, risk perception, and risk preparedness. The course will also cover laws and regulation, and disaster preparedness, various acts passed by the U.S. Congress to regulate water, air, and controlled substances.
Prerequisite: Undergraduate or equivalent physics, math, and chemistry
Fall, spring, 4 credits, ABCF grading

ESM 561 Crystal Growth Technology
The main goal of this course is to introduce graduate students to the fundamentals and physical principles that govern the process of crystal growth and show them how to apply those principles to design and engineer growth systems for different crystalline materials. While microscopic theory of nucleation and growth kinetics will be an essential part of this course, its core will mainly focus on applying transport phenomena and thermodynamics of chemical reactions to the design of processing reactors. As part of the academic requirements associated with this course, students will form teams and work on the virtual design of crystal growth reactors using software packages for transport phenomena modeling.
Fall, every year, 3 credits, ABCF grading

ESM 575 The Material World
The evolution of the material world starting from the Big Bang, the creation of stars and galaxies, the nucleosynthesis of the elements in supernova explosions, formation of the Earth and solar system, and human adaptation of Earth resources to create the modern world will be discussed. In this process we will discover the fundamental laws governing material behavior and explore the cosmic significance of our existence.
3 credits, ABCF grading

ESM 599 Research
Fall and spring, 1-12 credits, S/U grading
May be repeated for credit

ESM 600 Seminar in Surface Science
Discussions and reading on current problems in surface physics, chemistry, and crystallography.
Spring, 3 credits, ABCF grading

ESM 602 Seminar in Plasticity and Fracture
Intended for advanced students, especially those doing research in the area. Topics: detailed description of defects and their relations to mechanical structure; dislocation theory; plasticity and yield criteria; creep and fatigue; microscopic theory of fracture including ductile and brittle behavior and the relationship of plastic flow to cleavage.
Prerequisite: ESM 513
3 credits, ABCF grading

ESM 604 Seminar in Ultrasonic Methods and Internal Friction in Solids
Review of advanced measurement techniques in the field of ultrasonics coupled with quantitative descriptions of experimental variables related to the sample microstructure. Applications to optical, electrical, and mechanical properties are discussed. Use of ultrasonics for nondestructive evaluation is considered.
Prerequisite: ESM 513
Spring, 3 credits, ABCF grading

ESM 605 Advanced Diffraction Techniques
Advanced topics in diffraction theory including the dynamical theory in perfect and imperfect crystals and its applications in imaging methods. Other topics from the following list are pursued if time is available: EXAFS/EXELFS/SEXAFS; LEED/RHEED; small-angle scattering; Kossel line and electron channeling patterns; convergent beam diffraction; phonon scattering; glancing incidence X-ray diffraction; diffraction from defect structures; colored symmetry; holography.
Prerequisites: ESM 512 or permission of instructor
Fall, 3 credits, ABCF grading

ESM 606 Seminar in Optical Properties of Material
A survey of modern optical materials and their characterization. The properties of both glasses and crystalline materials are related to physical origin. Electro-optic, elasto-optic, and magneto-optic properties and their interrelations are related to applications in technology including laser systems, displays, and spectroscopy.
Fall, 3 credits, ABCF grading

ESM 608 Seminar in Catalysis
Introduction to homogeneous and heterogeneous catalysis. Geometric factors in catalysis. The kinetics of heterogeneous catalysis. Electronic factors in catalysis: metals, semiconductors, and surface species. Preparation and properties of metal surfaces. Porosity. Typical industrial processes, e.g., Fischer-Tropsch, ammonia synthesis, ammonia oxidation, etc.
Fall, 3 credits, ABCF grading

ESM 610 Seminar in Reactions in Inorganic Solids
Crystal growth and the nature of defects in inorganic solids. Crystallography and nucleation phenomena in selected inorganic single crystals. Theories of isothermal decomposition kinetics. Measurement of decomposition rates. Radiation effects and nature of radiation damage in inorganic solids. Photodecomposition and the underlying theories of photolysis.
Fall, 3 credits, ABCF grading

ESM 612 Seminar in Advanced Thermodynamics of Solids
The fundamentals of the thermodynamics of irreversible processes are presented and the theory applied to thermal diffusion, thermoelectric transport, and other coupled processes in solids. Thermodynamics of multicomponent phase equilibria. Diffusion, oxidation, and other rate processes in ternary and higher-order systems.
Prerequisite: ESM 511
Spring, 3 credits, ABCF grading

ESM 613 Seminar in Materials and Environment
Interactions between materials and their environments including corrosion, oxidation, absorption, and adsorption reactions. The influence of these reactions on the properties of materials, the design of materials resistant to these phenomena, alternative methods of protection, and the utilization of these reactions in promoting breakdown and deterioration of materials.
Spring, 3 credits, S/U grading

ESM 614 Seminar in Diffusion in Solids
Diffusion in solids is considered in detail, including solution of the transport equations for volume, grain boundary, and surface diffusion. Kirkendall effect and other diffusion phenomena, atomic mechanisms of diffusion, correlation effects, etc. Next, the theory of processes in which diffusion plays an important role is considered, such as ionic conduction, oxidation of metals, and the sintering of solids.
Spring, 3 credits, S/U grading

ESM 615 Seminar in Phase Transformations
The theory of phase transformations in solids is considered. Kinetics and mechanisms of nucleation and growth and martenistic transformations. Melting and solidification,

precipitation from solid solution, polymorphic transformations, eutectic and eutectoid reactions, second-order transitions, recrystallization, and other transformations in solids.
Fall, 3 credits, S/U grading

ESM 695 Graduate Internship
Participation in private corporations, public agencies, or non-profit institutions for ongoing research activities related to thesis research. Students will be required to have a faculty coordinator as well as a contact in the outside organization, to participate with them in regular consultations on the project, and to submit a final report to both. Not accepted for credit toward the M.S. degree.
Prerequisite: Permission of graduate program director
1-3 credits, S/U grading
May be repeated for credit

ESM 696 Special Problems in Materials Science
Supervised reading and discussion of selected publications in particular fields of materials science. This course is designed primarily for advanced graduate students who are, or expect to be, involved in research in these areas, although other students may enroll with permission of the instructor.
Fall and spring, 0-3 credits, ABCF grading
May be repeated for credit

ESM 697 Materials Science Colloquium
A weekly series of lectures and discussions by visitors, local faculty, and students presenting current research results.
Fall and spring, 0-3 credits, S/U grading
May be repeated for credit

ESM 698 Practicum in Teaching
Fall and spring, 0-3 credits, S/U grading
May be repeated for credit

ESM 699 Dissertation Research On Campus
Prerequisite: Advancement to candidacy (G5); major portion of research must take place on campus, at Cold Spring Harbor, or at Brookhaven National Lab
Fall, spring, and summer, 1-9 credits, S/U grading
May be repeated for credit

ESM 700 Dissertation Research Off Campus–Domestic
Prerequisite: Must be advanced to candidacy (G5); major portion of research will take place off campus, but in the U.S. and/or U.S. provinces (Brookhaven National Lab and Cold Spring Harbor Lab are considered on campus); all international students must enroll in one of the graduate student insurance plans and should be advised by an International Advisor
Fall, spring, and summer, 1-9 credits, S/U grading
May be repeated for credit

ESM 701 Dissertation Research Off Campus–International
Prerequisite: Must be advanced to candidacy (G5); major portion of research will take place outside the U.S. and/or U.S. provinces; domestic students have the option of the health plan and may also enroll in MEDEX; international students who are in their home country are not covered by mandatory health plan and must contact the Insurance Office for the insurance charge to be removed; international students who are not in their home country are charged for the mandatory health insurance (if they are to be covered by another insurance plan, they must file a waiver by the second week of classes; the charge will only be removed if the other plan is deemed comparable); all international students must receive clearance from an International Advisor
Fall, spring, and summer, 1-9 credits, S/U grading
May be repeated for credit

ESM 800 Full-time Summer Research
0 credit, S/U grading
May be repeated