DEPARTMENT OF MATERIALS SCIENCE and ENGINEERING

School of Engineering and Applied Science
University of Virginia
World Wide Web Site Location: http://www.virginia.edu/ms

The Department of Materials Science and Engineering offers graduate education and research programs in the structure, properties, processing and performance of materials. Emphasis is placed on developing an understanding of the general principles that govern the properties of materials using both macroscopic and microscopic points of view.

The Department provides a broad-based graduate education in materials, one component of which emphasizes the commonality among the various classes of engineering solids. Thus thermodynamics, kinetics, structural analysis and crystallography, defect theory, and principles of the solid state are strong features of our program. In addition, other courses relative to the application of materials and the relationships among materials properties, structure, and the manner in which materials have been processed are also offered. Extensive research programs complement formal course work. Active recent programs on environmental effects on material behavior, electronic materials, metals, polymers, tribology, composite materials, computational materials, and materials processing reflect the diversity of the faculty's research interests. The Department houses the Center for Light Metals, The Center for Electrochemical Sciences and Engineering, The NSF-MRSEC Center for the Nanoscopic Design of Materials, The MURI-Multi University Research Initiative, and the Intelligent Processing of Materials Laboratory.

The Department offers three graduate degrees: the M.S. (Master of Science in Materials Science and Engineering), the Ph.D. (Doctor of Philosophy in Materials Science and Engineering) and the M.M.S.E. (Master of Materials Science and Engineering). The M.S. degree requires satisfactory completion of 25 course credits beyond the bachelor's level and submission of a thesis. An additional 20 course credits is required for the Ph.D. degree. Ph.D. students must pass an oral and written qualifying examination and successfully defend their dissertation. Outstanding students may pursue the Ph.D. directly by petitioning the faculty to enter the master's bypass program. The M.M.S. is a non-thesis degree program intended for those working in technical, industrial, or government fields.

Department laboratories are located in the Materials Science and Engineering building and are well equipped with extensive state-of-the-art instrumentation for the investigation of all aspects of materials structure and properties. A modern analytical electron microscope facility is available which includes: a 400 kV high-resolution transmission electron microscope (TEM) with a point resolution of 0.17 nm; a 200 kV field-emission TEM equipped with an imaging filter and energy dispersive X-ray spectrometer (EDS); a 200 kV TEM/ STEM equipped with EDS and a variety of *in situ* specimen holders, and two scanning electron microscopes (SEMs) equipped with EDS; one also with wavelength dispersive spectrometers (WDS) and electron back scattering pattern (EBSP) facilities. The electron microscope and X-ray laboratories have dedicated computer processing facilities for data evaluation. X-ray diffraction systems provide facilities for a wide variety of single crystal and powder techniques. The polymer science laboratory offers facilities for infrared spectroscopy, viscosity, differential thermal analysis, automatic osmometry, and for the measurement of thermal, electrical, and optical properties of polymers and other macromolecules. Chemical vapor deposition facilities include new equipment for the preparation of electronic materials from metal-organic compounds.

Other laboratories are equipped for research in physical metallurgy, fatigue and fracture, corrosion, surface studies, thin film properties, and materials processing. Their facilities include: a low pressure plasma spray system; electron beam vapor processing facilities; continuous tape casting equipment; laser ultrasonic sensors; multi-frequency eddy current and dielectric spectroscopy sensors; fiber optic luminescence spectroscopy; ultra-high vacuum deposition units; electron beam and vacuum furnaces; heat treating equipment; a rolling mill; numerous mechanical testing machines; a hot isostatic press, an X-ray texture goniometer; potentiostats; solution analysis equipment; thermal desorption spectroscopy and electrochemical impedance spectroscopy systems; optical metallographs; and interference, polarizing, and hot stage microscopes with sophisticated image analysis and processing facilities. A fully equipped machine shop and instrument shop are adjacent to the research laboratories.

Computational facilities within the Department include a Silicon Graphics (SGI) Origin 2200 (8-node/6GB RAM) and Origin 3400 (16-node/8GB RAM) interconnected through a 0.5TB Raid storage array, and a host of workstations including IBM, SUN, SGI, and MacIntosh. University resources include an IBM SP2 parallel computer that has recently undergone a $2 million upgrade. Access to additional high-performance Cray, IBM and HP computing platforms is available under NPACI - the National Partnership for Advanced Computing Infrastructure – in which UVA is a contributing partner.

Graduate Course Descriptions

MSE 512, INTRODUCTION TO BIOMATERIALS.

Provides a multi-disciplinary perspective on the phenomenon and processes which govern material-tissue interactions with the soft tissue, hard tissue, and cardiovascular environments. Emphasizes both sides of the biomaterials interface, examining the events at the interface, and discussing topics on material durability and tissue compatibility.

MSE 524, MODELING IN MATERIALS SCIENCE.

Computational (primarily classical) methods of atomistic, mesoscopic, continuum, and multiscale modeling are discussed in the context of real materials-related problems (mechanical and thermodynamic properties, phase transformations, microstructure evolution during processing). Success stories and limitations of contemporary computational methods are considered. The emphasis of the course is on getting practical experience in designing and performing computer simulations. A number of pre-written codes are provided. Students use and modify the pre-written codes and write their own simulation and data analysis codes while working on their homework assignments and term projects.

MSE 532, DEFORMATION AND FRACTURE MECHANICS OF STRUCTURAL MATERIALS.

Deformation and fracture are considered through integration of materials science microstructure and solid mechanics principles, emphasizing the mechanical behavior of metallic alloys and engineering polymers. Metal deformation is understood based on elasticity theory and dislocation concepts. Fracture is understood based on continuum fracture mechanics and microstructural damage mechanisms. Additional topics include fatigue loading, elevated temperature behavior, material embrittlement, time-dependency, experimental design, and damage-tolerant life prediction.

MSE 567, ELECTRONIC, OPTICAL AND MAGNETIC PROPERTIES OF MATERIALS.

Explore the fundamental physical laws governing electrons in solids, and show how that knowledge can be applied to understanding electronic, optical and magnetic properties. Students will gain an understanding of how these properties vary between different types of materials, and thus why specific materials are optimal for important technological applications. It will also be shown how processing issues further define materials choices for specific applications.

MSE 601, MATERIALS STRUCTURE AND DEFECTS.

Provides fundamental understanding of the structure and properties of perfect and defective materials. Topics include: crystallography and crystal structures, point defects in materials, properties of dislocations, surface structure and energy, structure and properties of interphase boundaries.

MSE 602, MATERIALS CHARACTERIZATION.

Develops a broad understanding of the means used to characterize the properties of solids coupled with a fundamental understanding of the underlying mechanisms in the context of material science and engineering. The course is organized according to the type of physical property interest. The methods used to access properties are described through integration of the principals of materials science and physics. Methods more amendable to analysis of bulk properties are differentiated from those aimed at measurements of local/surface properties. Breadth is achieved at the expense of depth to provide a foundation for advanced courses.

MSE 604, SCANNING ELECTRON MICROSCOPY AND MICROANALYSIS.
Covers the physical principles of scanning microscopy and electron probe microanalysis. Lab demonstrations and experiments cover the operation of the SEM and EPMA. Applications of secondary and backscattered electron imaging, energy dispersive X-ray microanalysis, wave-analysis are applied to

materials characterization. Lab experiments may include either materials science or biological applications, depending on the interests of the student.

MSE 605, STRUCTURE AND PROPERTIES OF MATERIALS I.

First of a two-course sequence for first-year graduate students without a materials background or for qualified undergraduates. Topics covered include: atomic bonding, crystal structure, and crystal defects in their relationship to properties and behavior of materials (polymers, metals, and ceramics); phase equilibria and non-equilibrium phase transformation; metastable structures; solidification, and recystallization.

MSE 606, STRUCTURE AND PROPERTIES OF MATERIALS II.

Second of a two-course sequence for first-year graduate and qualified undergraduates. Principal topics are diffusion in solids; elastic, anelastic, plastic deformation; electronic and magnetic properties of materials. Emphasizes the relationships between microscopic mechanisms and macroscopic behavior of materials.

MSE 608, CHEMICAL AND ELECTROCHEMICAL PROPERTIES.

Introduces the concepts of electrode potential, double layer theory, surface charge, and electrode kinetics. These concepts are applied to subjects which include corrosion and embrittlement, energy conversion, batteries and fuel cells, electro-catalysis, electroanalysis, electro-chemical industrial processes, bioelectrochemistry and water treatment.

MSE 623, THERMODYNAMICS OF SOLIDS.

Emphasizes the understanding of thermal properties such as heat capacity, thermal expansion, and transitions in terms of the entropy and the other thermodynamic functions. Develops the relationships of the Gibbs and Helmholtz functions to equilibrium systems, reactions, and phase diagrams. Atomistic and statistical mechanical interpretations of crystalline and non-crystalline solids are linked to the general thermodynamical laws by the partition function. Nonequilibrium and irreversible processes in solids are discussed.

MSE 624, KINETICS OF SOLID-STATE REACTIONS.

Serves as an introduction to basic kinetic processes in materials, develops basic mathematical skills necessary for materials research, and reinforces basic numerical and computer programming skills. Students will learn to formulate the partial differential equations and boundary conditions used to describe basic materials phenomena in the solid state including mass and heat diffusion in single- and two-phase systems, the motion of planar phase boundaries, and interfacial reactions. Students will develop analytical and numerical techniques for solving these equations and will apply them to understanding microstructural evolution.

MSE 635, PHYSICAL METALLURGY OF LIGHT ALLOYS.

Develops the student's literacy in aluminum and titanium alloys used in the aerospace and automotive industries. Considers performance criteria and property requirements from design perspectives. Emphasizes processing-microstructure development, and structure-property relationships.

MSE 647, PHYSICAL METALLURGY OF TRANSITION-ELEMENT ALLOYS.

Reinforces fundamental concepts, introduces advanced topics, and develops literacy in the major alloy systems. Emphasizes microstructural evolution by composition and thermomechanical process control. Topics include phase diagrams, transformation kinetics, martensitic transformation, precipitation, diffusion, recrystallization, and solidification. Considers both experimental and model-simulation approaches.

MSE 662, MATHEMATICS OF MATERIALS SCIENCE.

Representative problems in materials science are studied in depth with emphasis on understanding the relationship between physical phenomena and their mathematical description. Topics include rate processes, anelasticity, eigenvalue problems, tensor calculus, and elasticity theory.

MSE 667, SEMICONDUCTOR MATERIALS AND DEVICES.

Provides an understanding of the fundamentals, materials, and engineering properties of semiconductors; and the integration of semiconductors with other materials to make optoelectronic and microelectronic devices. Topics include basic properties of electrons in solids; electronic, optical, thermal and mechanical properties of semiconductors; survey of available semiconductors and materials choice for device design; fundamental principles of important semiconductor devices; submicron engineering of semiconductors, metals, insulators & polymers for integrated circuit manufacturing; materials characterization techniques & other electronic materials.

MSE 691, 692, TOPICS IN MATERIALS SCIENCE.

A study of special subjects related to developments in materials science under the direction of members of the staff. Offered as required.

MSE 694, MATERIALS SCIENCE LABORATORY.

Introduces student to the specialized experimental techniques used in materials science research. Particular attention given to the techniques of X-ray diffractions and electron microscopy. The student is also introduced to several of the latest experimental methods such as field ion microscopy, electron spin resonance, low voltage electron diffraction, etc.

MSE 695, SUPERVISED PROJECT RESEARCH.

Formal record of student commitment to project research for Master of Science or Master of Materials Science degree under the guidance of a faculty advisor. May be repeated as necessary.

MSE 701, 702, MATERIALS SCIENCE SEMINAR.

Broad topics and in-depth subject treatment are presented. Related to research areas in materials science and involves active student participation.

MSE 703, ELECTRON MICROSCOPY OF CRYSTALS.

Analysis of the physical principles of microscopy and electron optics. attainment of high resolution; mass-thickness contrast; theory of diffraction contrast; scanning electron microscopy and applications to materials science; high-voltage electron microscopy.

MSE 706, ADVANCED ELECTRON MICROSCOPY.

Emphasis placed on the applications of advanced techniques of transmission and scanning electron microscopy to modern research problems in materials science and engineering. Microdiffraction and microanalysis, lattice imaging, and convergent beam diffraction in TEM and STEM are treated. In SEM, quantitative probe analysis techniques as well as back scattered electron imaging and channeling are covered.

MSE 712, DIFFUSIONAL PROCESSES IN MATERIALS.

An introduction to elasticity theory, the thermodynamics of stressed crystals, and diffuse interface theory with application to understanding microstructural evolution in bulk materials and thin films.

MSE 714, QUANTIZATION IN SOLIDS.

Quantization arising from eigenvalue problems is discussed in relation to the classical and quantum wave equations. This theory is applied to lattice vibrations (phonons) and electrons in a solid. Topics studied in detail include cohesion, thermal properties (e.g., specific heat and conductivity), electrical properties (e.g., metallic conductivity and semiconductor junctions) and optical properties (e.g., luminescence and photoconductivity).

MSE 722, SURFACE SCIENCE.

Analysis of the structure and thermodynamics of surfaces, with particular emphasis on the factors controlling chemical reactivity of surfaces; adsorption, catalysis, oxidation, and corrosion are considered from both theoretical and experimental viewpoints. Modern surface analytical techniques, such as Auger, ESCA, and SIMS, are considered.

MSE 731, MECHANICAL BEHAVIOR OF MATERIALS.

Study of the deformation of solids under stress; emphasizing the role of imperfections, state of stress, temperature and strain rate. Description of stress, strain, strain rate and elastic properties of materials comprise the opening topic. Fundamental aspects of crystal plasticity are then considered, along with the methods for strengthening crystals at low temperatures. Deformation at elevated temperatures and deformation maps are also covered. Emphasizes the relationships between microscopic mechanisms and macroscopic behavior of materials.

MSE 732, FRACTURE MECHANICS OF ENGINEERING MATERIALS.

Develops the tools necessary for fatigue and fracture control in structural materials. Continuum fracture mechanics principles are presented. Fracture modes are discussed from the interdisciplinary perspectives of continuum mechanics and microscopic plastic deformation/fracture mechanisms. Cleavage, ductile fracture, fatigue, and environmental cracking are included, with emphasis on micromechanical modeling.

MSE 734, PHASE TRANSFORMATIONS.

Fundamental theory of diffusional phase transformations in solid metals and alloys. Applications of thermodynamics to calculation of phase boundaries and driving forces for transformations. Theory of solid-solid nucleation, theory of diffusional growth, comparison of both theories with experiment. Applications of thermodynamics and of nucleation and growth theory to the principal experimental systematics of precipitation from solid solution, the massive transformations, the cellular and the pearlite reactions, martensite transformations, and the questions of the role of shear in diffusional phase transformations.

MSE 741, CRYSTAL DEFECT THEORY.

The nature and major effects of crystal defects on the properties of materials are studied, with particular emphasis on metals. The elasticity theory of dislocations is treated in depth.

MSE 751, POLYMER SCIENCE.

Emphasis is on the nature and types of polymers and on methods for studying them. Surveys chemical structures and methods of synthesis, and develops the physics of the special properties of polymers (e.g., rubber elasticity, tacticity, glass transitions, crystallization, dielectric and mechanical relaxation, and permselectivity). Discusses morphology of polymer systems and its influence on properties.

MSE 752, ADVANCED POLYMER SCIENCE II.

Focuses on experimental methods of polymer science. Detailed picture of polymer structure and properties developed by examining use of solutions (viscosity and chromatography), thermal (DSC, DTA, TGA), microscopic (electron and optical), spectroscopic (IR, Raman, NRM, mechanical and dielectric), scattering (neutron, X-ray, and visible light), and diffraction (neutron, electron and X-ray) techniques as applied to the characterization and study of polymeric materials.

MSE 757, MATERIALS PROCESSING.

Discusses scientific and technological bases of material processing. Emphasizes solidification, deformation, particulate and thermomechanical processing. Approached first from a fundamental point of view and then their current technological applications are discussed.

MSE 762, MODERN COMPOSITE TECHNOLOGY.

Technology of modern composite materials including basic principles, mechanics, reinforcements, mechanical properties and fracture characteristics, fabrication techniques, and applications. High performance filamentary reinforced materials are emphasized. The principles of chemical vapor deposition and the application of this technology to the area of composite materials are discussed.

MSE 771, ADVANCED ELECTROCHEMISTRY.

Course is highly specialized and details specific areas of corrosion of stainless steel, cyclic voltammetry, the adsorption of hydrogen on and diffusion of hydrogen through Palladium. Associated experimental methods are discussed.

MSE 791, 792. ADVANCED TOPICS IN MATERIALS SCIENCE.

Advanced level of special subjects related to developments in materials science under the direction of members of the staff. Offered as required.

MSE 791 PHYSICS OF SOLIDS.

This course on the fundamentals of the physics of solids is designed to develop selected topics in solid state theory relevant to modern materials science. The following topics will be emphasized: the crystalline state; amorphous solids; wave-particle diffraction in periodic structures; lattice vibrations; thermal properties of solids; Boltzmann and Bose-Einstein Statistics; Phonons; Electron Theory of Solids; Free Electron Theory of Metals; Fermi-Dirac Statistics; Band Theory of Solids; Brillouin Zones; Atomic Origin of Magnetism in Solids; Varieties of Magnetic Order; Cooperative Phenomena; Domain Magnetism; Superconductivity; Type-1 and Type-2 Superconductors; High Tc Superconductivity.

MSE 793, INDEPENDENT STUDY.

Detailed study of graduate course material on an independent basis under the guidance of a faculty member.

MSE 795, Supervised Project Research.

Formal record of student commitment to project research for Doctor of Philosophy degree under guidance of a faculty advisor. May be repeated as necessary.

MSE 897, GRADUATE TEACHING INSTRUCTION.

For master's students.

MSE 898, THESIS.

Formal record of student commitment to master's thesis research under the guidance of a faculty advisor. May be repeated as necessary.

MSE 997, GRADUATE TEACHING INSTRUCTION.

For doctoral students.

MSE 999, DISSERTATION.

Formal record of student commitment to doctoral research under the guidance of a faculty advisor. May be repeated as necessary.

MSE 791 PHYSICS OF SOLIDS.

This course on the fundamentals of the physics of solids is designed to develop selected topics in solid state theory relevant to modern materials science. The following topics will be emphasized: the crystalline state; amorphous solids; wave-particle diffraction in periodic structures; lattice vibrations; thermal properties of solids; Boltzmann and Bose-Einstein Statistics; Phonons; Electron Theory of Solids; Free Electron Theory of Metals; Fermi-Dirac Statistics; Band Theory of Solids; Brillouin Zones; Atomic Origin of Magnetism in Solids; Varieties of Magnetic Order; Cooperative Phenomena; Domain Magnetism; Superconductivity; Type-1 and Type-2 Superconductors; High Tc Superconductivity.