ENMA - ENGINEERING, MATERIALS

ENMA400 Introduction to Atomistic Modeling in Materials (3 Credits)
This is an introductory course designed to study atomistic modeling and simulation techniques used in materials research. This course covers the theories, methods, and applications of atomistic-scale modeling techniques in simulating, understanding, and predicting the properties of materials. Specific topics include: molecular statics using empirical force fields; quantum mechanical methods including density functional theory; molecular dynamics simulations; and Monte Carlo and kinetic Monte Carlo modeling.
Prerequisite: ENMA300, MATH206, and ENMA460.
Recommended: Basic knowledge in quantum mechanics (preferred but not required); basic knowledge in statistical mechanics (preferred but not required). Also offered as: ENMA600.
Credit Only Granted for: ENMA489A, ENMA400, ENMA698A, or ENMA600.
Formerly: ENMA489A.

ENMA401 Continuum Modeling of Materials (3 Credits)
Introduces continuum modeling techniques in materials science and engineering. This course covers and emphasizes the applications of continuum modeling techniques using COMSOL software package in simulating a range of materials phenomena and properties. Specific topics of continuum modeling include: The construction and analyses of continuum models using COMSOL software package; Structural mechanics; Heat transfer; Electrical current; Chemical species transport; Fluid flow; Multi-physics models coupling above phenomena.
Prerequisite: ENMA362, PHYS270, PHYS271, and MATH246; or equivalent; and ENMA165 or MATH206.
Restriction: Permission of ENGR-Materials Science & Engineering department.
Credit Only Granted for: ENMA401 or ENMA489C.
Formerly: ENMA489C.

ENMA410 Materials for Energy I (3 Credits)
The goal is to demonstrate the role of materials in solving one of the most critical socio-economic issues of our time, affordable and sustainable energy. There will be a discussion of U.S. and global energy and related environmental issues. Topics covered include: fuel cells and batteries (electrochemical energy conversion and storage); catalysts and membrane separations (fossil fuel and biomass energy conversion); and nuclear fuels.
Prerequisite: Minimum grade of C- in ENMA300; and permission of ENGR-Materials Science & Engineering department.
Credit Only Granted for: ENMA410 or ENMA489H.
Formerly: ENMA489H.

ENMA411 Materials for Energy II (3 Credits)
Demonstrates the role of materials in solving one of the most critical socio-economic issues of our time, affordable and sustainable energy. Materials for Energy is a two-part course based on material functionality; however, they are independent and neither is a prerequisite for the other. Materials for Energy II will focus on electrical, optical, thermal, and mechanically functional materials for energy devices. Solar cells, solar fuel, solar thermal, energy efficient lighting, building energy, thermoelectric and wind energy will be covered.
Prerequisite: Minimum grade of C- in ENMA300; and permission of ENGR-Materials Science & Engineering department.
Credit Only Granted for: ENMA411 or ENMA489I.
Formerly: ENMA489I.

ENMA412 Fundamentals of Photovoltaics (3 Credits)
Overview of the fundamentals of photovoltaic devices, including principles of operation, with emphasis on the materials science aspects of the different technologies available.
Prerequisite: ENMA300; and permission of ENGR-Materials Science & Engineering department.

ENMA414 Introduction to Solid State Ionics (3 Credits)
Solid State Ionics is the study of point defects in crystalline and non-crystalline solids; defect equilibria and transport; the influence of chemical and electric potentials, interfaces, and association; and the application of ionically conducting solids in solid-state electrochemical transducer systems and devices.
Prerequisite: ENMA300; and permission of ENGR-Materials Science & Engineering department.
Credit Only Granted for: ENMA414 or ENMA489W.
Formerly: ENMA489W.

ENMA421 Design of Composites (3 Credits)
Fundamentals of design, processing and selection composite materials for structural applications will be covered. The topics include a review of all classes of materials, an in-depth analysis of micro and macro mechanical behavior including interactions at the two-phase interfaces, modeling of composite morphologies for optimal microstructures, material aspects, cost considerations, processing methods including consideration of chemical reactions and stability of the interfaces, and materials selection considerations.
Restriction: Permission of ENGR-Materials Science & Engineering department.
Credit Only Granted for: ENMA421 or ENMA489A.
Formerly: ENMA489A.

ENMA422 Radiation Effects of Materials (3 Credits)
Ionizing radiation, radiation dosimetry and sensors, radiation processing, radiation effects on: polymers, metals, semiconductors, liquids, and gases. Radiation in advanced manufacturing, radiation-physical technology.
Prerequisite: ENMA300; and permission of ENGR-Materials Science & Engineering department.
Credit Only Granted for: ENMA422 or ENMA489E.
Formerly: ENMA489E.

ENMA425 Introduction to Biomaterials (3 Credits)
Examination of materials used in humans and other biological systems in terms of the relationships between structure, fundamental properties and functional behavior. Replacement materials such as implants, assistive devices such as insulin pumps and pacemakers, drug delivery systems, biosensors, engineered materials such as artificial skin and bone growth scaffolds, and biocompatibility will be covered.
Recommended: ENMA300.
Restriction: Permission of ENGR-Materials Science & Engineering department.
Credit Only Granted for: BIOE453, CHBE457, or ENMA425.

ENMA426 Reliability of Materials (3 Credits)
Students are taught the basic degradation mechanisms of materials, through the understanding of the physics, chemistry, mechanics of such mechanisms. Mechanical failure mechanisms concentrate on fatigue, and creep. Chemical failure mechanisms emphasize corrosion and oxidation. Physical mechanisms such as diffusion, electromigration, defects and defect migration, surface trapping mechanisms, charge creation and migration are also included.
Restriction: Permission of ENGR-Materials Science & Engineering department.
Credit Only Granted for: ENMA426 or ENMA489R.
Formerly: ENMA489R.

ENMA431 Nanomechanics of Biomaterials (3 Credits)
Focuses on the latest scientific developments and discoveries in the nanoscale structure and properties of biological materials. The course begins with introductory lectures on the various nanostructures of biomaterials, and their physiological roles under mechanical forces. General aspects of biopolymers, protein folding, and self-assembly are also covered. Next, a series of in-depth lectures are presented on the characterization methods of nanomechanical properties using single molecule techniques. Finally, current applications of nanobiomaterials in the area of molecular machines, molecular self-assembly, and nanoscaffold are discussed.
Prerequisite: ENMA300; and permission of ENGR-Materials Science & Engineering department.
Credit Only Granted for: ENMA431 or ENMA489B.
Formerly: ENMA489B.

ENMA435 Wide Bandgap Materials and Devices (3 Credits)
Presents the materials science of wide bandgap materials and analyzes the defects present in such materials from a device performance point of view.
Prerequisite: ENMA300 and ENMA465.
Corequisite: ENMA460.
Jointly offered with: ENMA635.
Restriction: Permission of ENGR-Materials Science & Engineering department.
Credit Only Granted for: ENMA435 or ENMA635.

ENMA436 Introduction to Quantum Materials and Devices (3 Credits)
Quantum materials and devices are an emerging field in materials engineering and physics which offer new approaches to electronics and photonics. This course serves as an introduction to quantum materials and their applications in quantum technologies. It will teach concepts needed to understand the quantum mechanical properties of materials and connect their fundamental properties to quantum device applications. Topics will include low-dimensional materials, strongly correlated electron systems, topology in solids, and light-matter interactions
Prerequisite: ENMA460 and ENMA461 .
Jointly offered with: ENMA636.
Restriction: Permission of ENGR-Materials Science & Engineering department.
Credit Only Granted for: ENMA436 or ENMA636.

ENMA437 Machine Learning for Materials Science (3 Credits)
Familiarizes students with basic as well as state of the art knowledge of machine learning and its applications to materials science and engineering. Covers the range of machine learning topics with applications including feature identification and extraction, determining predictive descriptors, uncertainty analysis, and identifying the most informative experiment to perform next. One focus of the class is to build the skills necessary for developing an autonomous materials research system, where machine learning controls experiment design, execution, and analysis in a closed-loop.
Prerequisite: MATH206, ENMA300, and MATH461.
Jointly offered with: ENMA637.
Restriction: Permission of ENGR-Materials Science & Engineering department.
Credit Only Granted for: ENMA489L, ENMA437 or ENMA637.
Formerly: ENMA489L.

ENMA440 Nano Plasma Processing of Materials (3 Credits)
Sustaining mechanisms of plasmas are covered, especially low-pressure electrical gas discharges, fundamental plasma physics, sheath formation, electric and magnetic field effects, plasma-surface interactions in chemically reactive systems, plasma diagnostic techniques and selected industrial applications of low pressure plasmas.
Restriction: Permission of ENGR-Materials Science & Engineering department.
Credit Only Granted for: ENMA440, ENMA489P, ENMA640, or ENMA698P.
Formerly: ENMA489P.

ENMA441 Characterization of Materials (3 Credits)
Techniques to characterize the properties of materials whose characteristic dimensions range from nanometers to macroscopic. These include conventional crystalline and noncrystalline materials, with a special attention to materials of current technological interest. The course will include recent results from the scientific literature.
Prerequisite: ENMA300, ENMA165 or MATH206.
Restriction: Permission of ENGR-Materials Science & Engineering department; and senior standing.
Credit Only Granted for: ENMA489T or ENMA441.
Formerly: ENMA489T.

ENMA442 Nanomaterials (3 Credits)
An exploration of materials whose structure places them at the boundary between small objects and large molecules. Having characteristic dimensions in the range of 1-100 nanometers, these materials are difficult to synthesize and characterize but are nevertheless at the forefront of science and technology in many fields. Also, the methods for creating, manipulating and measuring these materials with an emphasis on the current scientific literature will be covered. The novel properties and potential applications will also be addressed.
Restriction: Permission of ENGR-Materials Science & Engineering department.
Credit Only Granted for: ENMA442 or ENMA489N.
Formerly: ENMA489N.

ENMA443 Phontonic Materials, Devices and Reliability (3 Credits)
The course focuses on the understanding of the basic optical processes in semiconductors, dielectrics and organic materials. The application of such materials in systems composed of waveguides, light emitting diodes and lasers, as well as modulators is developed.
Restriction: Permission of ENGR-Materials Science & Engineering department; and junior standing or higher.
Credit Only Granted for: ENMA443 or ENMA489Z.
Formerly: ENMA489Z.

ENMA445 Liquid Crystals and Structured Soft Materials (3 Credits)
Elective course on the properties and behavior of liquid crystals and related soft materials, and their relationship to biomaterials and to applications.
Prerequisite: MATH246, PHYS270, and PHYS271.
Restriction: Permission of ENGR-Materials Science & Engineering department.
Credit Only Granted for: ENMA445 or ENMA489L.
Formerly: ENMA489L.

ENMA460 Introduction to Solid State Physics (3 Credits)
Classes of materials; introduction to basic ideal and real materials' behavior including mechanical, electrical, thermal, magnetic and optical responses of materials; importance of microstructure in behavior. One application of each property will be discussed in detail.
Prerequisite: PHYS271, PHYS270, and MATH241.
Cross-listed with: PHYS431.
Restriction: Junior standing or higher; and must be in the Engineering: Materials Science program or Physics program.
Credit Only Granted for: ENMA460 or PHYS431.
Additional Information: Materials Engineering students take ENMA460 and Physics students take PHYS431.

ENMA461 Thermodynamics of Materials (3 Credits)
Thermodynamic aspects of materials; basic concepts and their application in design and processing of materials and systems. Topics include: energy, entropy, adiabatic and isothermal processes, internal and free energy, heat capacity, phase equilibria and surfaces and interfaces.
Prerequisite: ENMA300.
Restriction: Junior standing or higher.

ENMA463 Macroprocessing of Materials (3 Credits)
Processing of modern, bulk engineering materials. Raw materials, forming, firing, finishing and joining. More emphasis on metals and ceramics than polymers.
Prerequisite: ENMA300.
Restriction: Junior standing or higher.

ENMA464 Environmental Effects on Engineering Materials (3 Credits)
Introduction to the phenomena associated with the resistance of materials to damage under severe environmental conditions. Oxidation, corrosion, stress corrosion, corrosion fatigue and radiation damage are examined from the point of view of mechanism and influence on the properties of materials. Methods of corrosion protection and criteria for selection of materials for use in radiation environments.
Prerequisite: ENMA300. Or permission of ENGR-Materials Science & Engineering department; and permission of instructor.

ENMA465 Microprocessing Materials (3 Credits)
Micro and nanoscale processing of materials. Emphasis on thin film processing for advanced technologies.
Prerequisite: ENMA300.
Restriction: Permission of ENGR-Materials Science & Engineering department.
Credit Only Granted for: ENMA363, ENMA489B, or ENMA465.
Formerly: ENMA363.

ENMA466 Advanced Materials Fabrication Laboratory (3 Credits)
This course allows students an opportunity to study advanced materials systems in depth through a combination of lectures and hands-on laboratory experiments. Students will be trained in materials processing and characterization techniques. Each student will fabricate materials and devices in our state-of-the-art nanofabrication clean room facility (Fablab), as well as evaluate them using a variety of characterization techniques.
Prerequisite: ENMA465; and permission of ENGR-Materials Science & Engineering department.

ENMA470 Materials Selection for Engineering Design (3 Credits)
Students will learn about materials classes, properties, limitations and applications and the methodology of materials selection in engineering design.
Prerequisite: Permission of ENGR-Materials Science & Engineering department.
Restriction: Junior standing or higher.
Credit Only Granted for: ENMA 470 or ENMA 489O.
Formerly: ENMA 489O.

ENMA471 Kinetics, Diffusion and Phase Transformations (3 Credits)
Fundamentals of diffusion, the kinetics of reactions including nucleation and growth and phase transformations in materials.
Prerequisite: Must have completed or be concurrently enrolled in ENMA461.
Restriction: Junior standing or higher; or permission of ENGR-Materials Science & Engineering department.

ENMA472 Additive Manufacturing of Materials (3 Credits)
Additive manufacturing approaches for metals, ceramics and polymers will be explored in terms of manufacturability and how processing parameters affect microstructure and properties. The course will include projects, including a Terrapin Works project to design and build a part, to develop an understanding of the current state of additive manufacturing, its future promise and its limitations.
Prerequisite: ENMA300.
Restriction: Must be in Engineering: Materials Science program.
Credit Only Granted for: ENMA472 or ENMA672.

ENMA473 Engineering Using High Strength Metals and Alloys (3 Credits)
This is a class focused on the materials engineering challenges of applying high strength metals and alloys to solutions. The extraordinary properties of these alloys derive from (1) highly metastable microstructures, (2) high strengths and melting points of the base metals, (3) complicated processing and fabrication procedures, and (4) their resulting complex behavior in extreme environments. This course will give you the knowledge base you need to select, apply and troubleshoot the performance of high strength metals and alloys in a variety of applications.
Prerequisite: ENMA300, ENMA362, and ENMA461; and permission of ENGR-Materials Science & Engineering department.

ENMA474 Introduction to Computational Materials Science (3 Credits)
This is an introductory course aiming for junior and senior undergraduate students to study atomistic modeling and simulation techniques that are used in materials science. This course covers the theories and applications of atomistic scale modeling techniques to simulate, understand, and predict the properties of materials. Topics include: molecular statics, quantum mechanical methods, molecular dynamics simulations and Monte Carlo simulations.
Restriction: Permission of ENGR-Materials Science & Engineering department.
Credit Only Granted for: ENMA474 or ENMA489A.
Formerly: ENMA489A.

ENMA475 Fundamentals of Diffraction Techniques in Materials Science (3 Credits)
This course looks at the advanced methods of x-ray scattering/diffraction available thanks to the more powerful sources available to us. The availability of these sources enables us to study liquid crystals, polymers, nanomaterials, quasiorganized materials (including nano) and disordered materials.
Prerequisite: MATH246, PHYS270, and PHYS271.
Restriction: Permission of ENGR-Materials Science & Engineering department.
Credit Only Granted for: ENMA475 or ENMA489M.
Formerly: ENMA489M.

ENMA476 NanoManufacturing: Materials Design and Systems Integration (3 Credits)
The fundamentals of nanomanufacturing based on state-of-the-art and future prospects in materials design and systems integration. The course examines functional nanomaterials design and synthesis, structural assembly from nanoscale to macroscale, and device fabrication. Distinct from the current curricular paradigm in many nanotechnology programs that focus on underlying science, this course emphasizes the immediate need for scale-up, process robustness, and system integration issues. Featuring case studies from industry, end of chapter problems, and study questions, the course is for upper-level undergraduate and graduate students, who are interested in the future of manufacturing innovation and technology.
Restriction: Must be in Engineering: Materials Science program.

ENMA481 Introduction to Electronic and Optical Materials (3 Credits)
Electronic, optical and magnetic properties of materials. Emphasis on materials for advanced optoelectronic and magnetic devices and the relationship between properties and the processing/fabrication conditions.
Prerequisite: ENMA300; or students who have taken courses with comparable content may contact the department.

ENMA482 Introduction to Electron Microscopy (3 Credits)
An introduction of the basic principles of operation for modern electron microscopes. Details will be given on the construction of microscopes, their basic operation, and the types of questions that can be addressed with an electron microscope. Emphasis will be placed on a conceptual understanding of the underlying theories. Where appropriate, mathematical descriptions will be utilized. Upon completion of this course, students will be excepted to have a basic understanding sufficient to give interpretations of microscopy images and to suggest the correct tool or approach for certain research studies.
Prerequisite: PHYS142, PHYS122, or PHYS260.
Credit Only Granted for: ENMA482 or ENMA489J.
Formerly: ENMA489J.

ENMA484 Fundamentals of Finite Element Modeling (3 Credits)
A brief review of mechanical behavior of materials, introduction to Finite Element Modeling (FEM), and procedures for predicting mechanical behavior of materials by FEM using computer software (at present ANSYS). The FEM procedures include, setting up the model, mesh generation, data input and interpretation of the results.
Restriction: Permission of ENGR-Materials Science & Engineering department.
Credit Only Granted for: ENMA484 or ENMA489F.
Formerly: ENMA489F.

ENMA486 Seminar in Materials Science and Engineering (1 Credit)
Current research in materials science and engineering and related fields. The lectures are presented by scientists and engineers from academia, national laboratory, US government, etc., in the format of seminars.
Restriction: Must be in Engineering: Materials Science program.

ENMA487 Capstone Preparation (1 Credit)
In preparation for the senior level design course, students will do background research and develop white papers from which teams will form around short listed design projects. The projects should focus on a society, industry, military or technological based problem in Materials Science and Engineering leading to a design and strategy to address the problem in the following course, ENMA 490. The course will include written and oral presentations of the white papers and team proposals.
Restriction: Must be in Engineering: Materials Science program; and senior standing; and permission of ENGR-Materials Science & Engineering department.

ENMA489 Selected Topics in Engineering Materials (3 Credits)
Selected topics of current importance in materials science and engineering.
Restriction: Permission of ENGR-Materials Science & Engineering department.
Repeatable to: 12 credits if content differs.

ENMA490 Materials Design (3 Credits)
Capstone design course. Students work in teams on projects evaluating a society or industry based materials problem and then design and evaluate a strategy to minimize or eliminate the problem; includes written and oral presentations.
Prerequisite: Minimum grade of C- in ENMA487.
Restriction: Senior standing.

ENMA495 Polymeric Engineering Materials I (3 Credits)
Study of polymeric engineering materials and the relationship to structural type. Elasticity, viscoelasticity, anelasticity and plasticity of single and multiphase materials. Emphasis is on polymetric materials.
Prerequisite: ENMA300.
Restriction: Permission of ENGR-Materials Science & Engineering department.

ENMA496 Polymeric Materials: Structure, Property, and Processing (3 Credits)
An intermediate level treatment of structures of polymers. An introduction to mechanical properties and processing of polymeric materials. Emphasis will be on how to establish the structure-property relationship and on how to achieve such understanding via different characterization methods.
Prerequisite: ENMA300; and permission of ENGR-Materials Science & Engineering department.
Cross-listed with: CHBE496.
Credit Only Granted for: ENMA496 or CHBE496.

ENMA499 Senior Laboratory Project (1-3 Credits)
Students work with a faculty member on an individual laboratory project in one or more of the areas of engineering materials. Students will design and carry out experiments, interpret data and prepare a comprehensive laboratory report.
Restriction: Permission of ENGR-Materials Science & Engineering department; and senior standing.

ENMA600 Advanced Atomistic Modeling in Materials (3 Credits)
This is an advanced course designed to study atomistic modeling and simulation techniques used in materials research. This course covers the theories, methods, and applications of atomistic-scale modeling techniques in simulating, understanding, and predicting the properties of materials. Specific topics include: molecular statics using empirical force fields; quantum mechanical methods including density functional theory; molecular dynamics simulations; and Monte Carlo and kinetic Monte Carlo modeling.
Prerequisite: Permission of ENGR-Materials Science & Engineering department.
Credit Only Granted for: ENMA600, ENMA 698A, ENMA400 or ENMA489A.
Formerly: ENMA698A.

ENMA601 Continuum Modeling of Materials (3 Credits)
An introductory course of continuum modeling in materials science and engineering. This course covers and emphasizes the applications of continuum modeling techniques using COMSOL software package in simulating a range of materials phenomena and properties.
Jointly offered with: ENMA401.
Restriction: Permission of ENGR-Materials Science & Engineering department.
Credit Only Granted for: ENMA401, ENMA601 or ENMA698C.
Formerly: ENMA698C.

ENMA613 Materials Science of Quantum Computing (3 Credits)
Quantum computing is the emerging field that attempts to perform information processing on a quantum mechanical state (qubit). This graduate level course targets advanced undergraduate and beginning graduate students for an introduction to this field of applied physics and the related material structures needed for elementary quantum computing. This course focuses on targeted topics of quantum mechanics and solid state physics as applicable to ion trap qubits, electron spin qubits, and superconducting qubits with connections to actual material structures their design and means of fabrication.
Prerequisite: Permission of ENGR-Materials Science & Engineering department.
Recommended: Strongly recommended coursework in introduction to materials science, electronic materials, solid state physics, quantum mechanics and basic knowledge in computer programming or MATLAB.

ENMA614 Advanced Solid State Ionics (3 Credits)
Advanced solid state ionics is the higher level study of point defects in crystalline and non-crystalline solids; defect equilibria and transport; the influence of chemical and electric potentials, interfaces, and association; and the application of ionically conducting solids in solid-state electrochemical transducer systems and devices.
Prerequisite: Permission of ENGR-Materials Science & Engineering department.
Credit Only Granted for: ENMA 614 or ENMA 698W.
Formerly: ENMA 698W.

ENMA615 Advanced Archeology meets Technology (3 Credits)
Focus on the application of scientific methods of analysis to archaeological materials including bone, stone, pottery, and metal. Methods include absolute dating, remote sensing, optical and SEM microscopy, elemental and isotopic analysis. Laboratory sections provide hands-on experience with a variety of archaeological materials and analytical methods.
Prerequisite: Permission of ENGR-Materials Science & Engineering department.
Recommended: Some knowledge of archaeology and archaeological methods, geology or chemistry is useful, but not required.

ENMA620 Polymer Physics (3 Credits)
The thermodynamics, structure, morphology and properties of polymers. Developing an understanding of the relationships between theory and observed behavior in polymeric materials.
Prerequisite: ENMA471; or permission of instructor.
Restriction: Permission of ENGR-Materials Science & Engineering department.

ENMA621 Advanced Design Composite Materials (3 Credits)
Fundamentals of design, processing, and selection of composite materials for structural applications are covered. The topics include a review of all classes of engineering materials, an in-depth analysis of micro and macro mechanical behavior including interactions at the two-phase interfaces, modeling of composite morphologies for optimal microstructures, material aspects, cost considerations, processing methods- including consideration of chemical reactions, stability of the interfaces and material selection.
Restriction: Permission of ENGR-Materials Science & Engineering department.
Credit Only Granted for: ENMA621 or ENMA698A.
Formerly: ENMA698A.

ENMA624 Radiation Engineering (3 Credits)
Ionizing radiation, radiation dosimetry and sensors, radiation processing, radiation effects on ; polymers, metals, semiconductors, liquid, and gas, radiation in advance manufacturing, radiation-physical technology.
Restriction: Permission of ENGR-Materials Science & Engineering department.
Credit Only Granted for: ENMA624 or ENMA698E.
Formerly: ENMA698E.

ENMA625 Biomaterials (3 Credits)
Examination of materials used in humans and other biological systems in terms of the relationships between structure, fundamental properties and functional behavior. Replacement materials such as implants, assistive devices such as insulin pumps and pacemakers, drug delivery systems, biosensors, engineered materials such as artificial skin and bone growth scaffolds, and biocompatibility will be covered.
Restriction: Permission of ENGR-Materials Science & Engineering department.
Credit Only Granted for: ENMA425, ENMA698I, BIOE698I, or ENBE453.
Formerly: ENMA698I.

ENMA626 Fundamentals of Failure Mechanisms (3 Credits)
Advanced failure mechanisms in reliability engineering wiil be taught from a basic materials and defects point of view. The methods of predicting the physics of failure of devices, materials, components and systems are reviewed. The main emphasis will be given to basic degradation mechanisms through understanding the physics, chemistry, and mechanics of such mechanisms. Mechanical failures are introduced through understanding fatigue, creep and yielding in materials, devices and components. The principles of cumulative damage and mechanical yielding theory are taught. The concepts of reliability growth, accelerated life testing, environmental testing are introduced. Physical, chemical and thermal related failures are introduced through a basic understanding of degradation mechanisms such as diffusion, electromigration, defects and defect migration. The failure mechanisms in basic material types will be taught. Failure mechanisms observed in real electronic devices and electronic packaging will also be presented. Problems related to manufacturing, and microelectronics will be analyzed. Mechanical failures are emphasized from the point of view of complex fatigue theory.
Cross-listed with: ENRE600.
Restriction: Permission of ENGR-Mechanical Engineering.
Credit Only Granted for: ENMA626, ENMA698M, ENMA698R, or ENRE600.

ENMA627 Nanotechnology Characterization (3 Credits)
Techniques to characterize the properties of materials whose characteristic dimensions are a few to a few hundred nanometers, including "conventional" nanocrystalline materials, but concentrating on "novel" nanomaterials: carbon nanotubes, quantum dots, quantum wires, and quantum wells will be covered. The emphasis is on recent results from the scientific literature concerning those properties that make nanostructures interesting: quantum effects, novel transport phenomena, enhanced mechanical properties associated with localization and with small crystalline size.
Credit Only Granted for: ENMA627 or ENME698T.
Formerly: ENMA698T.

ENMA630 Advanced Nanosized Materials: Synthesis and Utilization (3 Credits)
This course covers fundamental theory and fabrication-related aspects of nanoscale materials science. Topics: Quantization of energy level in solids and its effect on properties. Nucleation, growth and aging. Nano-epitaxy. Anisotropic crystal engineering. Electrical Transport. Nano-magnetism. Properties of carbon nanotubes. Applications in electronics, optics, data storage, energy and biomedicine.
Restriction: Permission of ENGR-Materials Science & Engineering department.
Credit Only Granted for: ENMA630 or ENMA6998G.
Formerly: ENMA698G.

ENMA631 Advanced Nanomechanics of Biomaterials (3 Credits)
Students will develop understanding of the latest scientific developments and discoveries in the nanoscale structure and properties of biological materials. Topics include nanostructures of biomaterials, physiological roles under mechanical forces, biopolymers, protein folding, and self-assembly. Also included are characterization methods of nanomechanical properties using single molecule techniques. Current applications of nanobiomaterials in the area of molecular machines, molecular self-assembly, and nanoscaffold are discussed.
Prerequisite: Permission of ENGR-Materials Science & Engineering department.
Credit Only Granted for: ENMA631 or ENMA698B.
Formerly: ENMA698B.

ENMA633 Advanced Characterization of Soft Matter Materials (3 Credits)
This course is focused on both the theories and experimental works of studying structure and dynamics of soft matter materials using scattering techniques (light, x-ray and neutron scattering). These scattering techniques can probe the structure from a few Angstrom to micrometer and the dynamics from picosecond to second, are thus widely used to reveal the structure-performance relationship of different materials. The course discusses the physics principles of these techniques and explains the details of general theories and commonly used models in characterizing soft matter materials such as polymer, protein, colloidal, thin film, and gel systems.
Restriction: Permission of ENGR-Materials Science & Engineering department.

ENMA635 Wide Bandgap Materials and Devices (3 Credits)
Presents the materials science of wide bandgap materials and analyzes the defects present in such materials from a device performance point of view.
Jointly offered with: ENMA435.
Restriction: Permission of ENGR-Materials Science & Engineering department.
Credit Only Granted for: ENMA435 or ENMA635.

ENMA636 Introduction to Quantum Materials and Devices (3 Credits)
Quantum materials and devices are an emerging field in materials engineering and physics which offer new approaches to electronics and photonics. This course serves as an introduction to quantum materials and their applications in quantum technologies. It will teach concepts needed to understand the quantum mechanical properties of materials and connect their fundamental properties to quantum device applications. Topics will include low-dimensional materials, strongly correlated electron systems, topology in solids, and light-matter interactions.
Prerequisite: ENMA650 and ENMA660 .
Jointly offered with: ENMA436.
Restriction: Permission of ENGR-Materials Science & Engineering department.
Credit Only Granted for: ENMA436 or ENMA636.

ENMA637 Machine Learning for Materials Science (3 Credits)
Familiarizes students with basic as well as state of the art knowledge of machine learning and its applications to materials science and engineering. Covers the range of machine learning topics with applications including feature identification and extraction, determining predictive descriptors, uncertainty analysis, and identifying the most informative experiment to perform next. One focus of the class is to build the skills necessary for developing an autonomous materials research system, where machine learning controls experiment design, execution, and analysis in a closed-loop.
Prerequisite: MATH461.
Recommended: Python knowledge.
Jointly offered with: ENMA437.
Restriction: Permission of ENGR-Materials Science & Engineering department.
Credit Only Granted for: ENMA437, ENMA489L, or ENMA637.

ENMA640 Advanced Nano Processing of Materials with Plasma (3 Credits)
Plasmas are used to control the micro-and Nanoscale level structure of materials including patterning at the micro-and nanoscale level using plasma etching techniques. The course establishes the scientific understanding required for the efficient production of nano-structure using plasma techniques.
Restriction: Permission of ENGR-Materials Science & Engineering department.
Credit Only Granted for: ENMA440, ENMA489P, ENMA698P, or ENMA640.
Formerly: ENMA698P.

ENMA641 Nanotechnology Characterization (3 Credits)
Techniques to characterize the properties of materials whose characteristic dimensions are a few to a few hundred nanometers, including conventional nanocrystalline materials, but concentrating on novel nanomaterials: carbon nanotubes, quantum dots, quantum wires, and quantum wells are covered. The emphasis is on recent results from the scientific literature concerning those properties that make nanostructures interesting: quantum effects, novel transport phenomena, enhanced mechanical properties associated with localization and with small crystallite size.
Restriction: Permission of ENGR-Materials Science & Engineering department.
Credit Only Granted for: ENMA698T or ENMA641.
Formerly: ENMA698T.

ENMA642 Current Trends in Nanomaterials (3 Credits)
Presents a historical and contemporary perspective of the trends of development of nanomaterials. Having characteristic dimensions in the range of 1-100 nanometers, these materials are difficult to synthesize a nd characterize but are nevertheless at the forefront of science and tec hnology in many fields. Through detailed analysis of the current literat ure, all students will develop a sense for not only where the science an d technology has come but also where it is going.
Credit Only Granted for: ENMA642 or ENMA698N.
Formerly: ENMA698N.

ENMA643 Advanced Photonic Materials (3 Credits)
The understanding of the basic optical processes in photonic devices and systems compsed of waveguides, light emitting diodes and lasers, as well as modulators is developed. Lectures on basic degradation mechanisms of such systems will be presented. The area of organic based LED reliability will be covered from the point of view of the stability of the organic-inorganic interface.
Restriction: Permission of ENGR-Materials Science & Engineering department.
Credit Only Granted for: ENMA698Z, ENRE648Z, or ENMA643.
Formerly: ENMA698Z.

ENMA645 Advanced Liquid Crystals and Other Monomeric Soft Matter Materials (3 Credits)
Elective course on the properties and behavior of liquid crystal and related soft materials, and their relationship to biomaterials and applications.
Restriction: Permission of ENGR-Materials Science & Engineering department.

ENMA650 Nanometer Structure of Materials (3 Credits)
The basic concepts required for understanding nanostructured materials and their behavior will be covered. Topics covered include the structural aspects of crystalline and amorphous solids and relationships to bonding types, point and space groups. Summary of diffraction theory and practice. The reciprocal lattice. Relationships of the microscopically measured properties to crystal symmetry. Structural aspects of defects in crystalline solids.
Prerequisite: ENMA460; or students who have taken courses with comparable content may contact the department. And permission of ENGR-Materials Science & Engineering department.

ENMA659 Special Topics in Electronic Materials (3 Credits)
Topics of current interest in the design and manufacture of electronic materials.
Restriction: Permission of ENGR-Materials Science & Engineering department.
Repeatable to: 6 credits if content differs.

ENMA660 Thermodynamics in Materials Science (3 Credits)
Thermodynamics of engineering solids. Thermal, diffusional and mechanical interactions in macroscopic systems. Systems in thermal contact, systems in thermal and diffusive contact, systems in thermal and mechanical contact.
Corequisite: ENMA650.
Restriction: Permission of ENGR-Materials Science & Engineering department.

ENMA661 Kinetics of Reactions in Materials (3 Credits)
The theory of thermally activated processes in solids as applied to diffusion, nucleation and interface motion. Cooperative and diffusionless transformations. Applications selected from processes such as allotropic transformations, precipitation, martensite formation, solidification, ordering, and corrosion.
Prerequisite: ENMA660.
Restriction: Permission of ENGR-Materials Science & Engineering department.

ENMA662 Advanced Smart Materials (3 Credits)
This course will cover the three ferroic materials, ferromagnetic, ferroelectric, and ferroelastic (also known as Shape Memory Alloy, SMA) as well as materials that are simultaneously ferromagnetic and ferroelectric etc. Their similarities and differences will be identified and their atomic level and crystal structure examined. Phase transformations are very important and will be treated in some detail. Applications, e.g. permanent magnets, electronic magnetic materials, digital storage elements, actuators and sensors as well as SMAs for vision glasses, self-adjusting valves and the like will be covered.
Restriction: Permission of ENGR-Materials Science & Engineering department.

ENMA664 Advanced Environmental Effects on Engineering Materials (3 Credits)
Introduction to the phenomena associated with the resistance of materials to damage under severe environmental conditions. Oxidation, corrosion, stress corrosion, corrosion fatigue and radiation damage are examined from the point of view of mechanism and influence on the properties of materials. Methods of corrosion protection and criteria for selection of materials for use in radiation related environments.
Credit Only Granted for: ENMA664 or ENMA698K.
Formerly: ENMA698K.

ENMA669 Special Topics in the Chemical Physics of Materials (3 Credits)
Restriction: Permission of ENGR-Materials Science & Engineering department; and permission of instructor.

ENMA671 Defects in Materials (3 Credits)
Fundamental aspects of point (electronic and atomic) defects, dislocations, and surfaces and interfaces in materials. Defect interactions, defect models, and effects of zero, one and two dimensional defects on material behavior.
Restriction: Permission of ENGR-Materials Science & Engineering department.

ENMA674 Advanced Computational Materials Science (3 Credits)
An introduction for beginning graduate students to study atomistic modeling and simulation techniques that are used in materials science. Theories and applications of atomistic scale modeling techniques to simulate, understand, and predict the properties of materials will be covered. Topics include: molecular statics, quantum mechanical methods, molecular dynamics simulations and Monte Carlo simulations.
Restriction: Permission of ENGR-Materials Science & Engineering department.
Credit Only Granted for: ENMA674 or ENMA 698A.
Formerly: ENMA698A.

ENMA679 Special Topics in the Mechanical Behavior of Materials (3 Credits)
Topics of current interest in the mechanical behavior of materials.
Restriction: Permission of ENGR-Materials Science & Engineering department.

ENMA680 Determination of Structure, Chemical Composition and Defects in Materials (3 Credits)
Basic principles of electron microscopy theory, electron diffraction, and imaging theory. The electron beam sample interaction that gives rise to different signals is related to the structural and compositional information that is obtained from a sample using a TEM. The most common TEM techniques for structural characterization of a sample, namely, electron diffraction, bright/dark field imaging, and high resolution lattice imaging are discussed. Compositional information obtained from x-ray fluorescence and electron energy loss as well as the resolution of these techniques is also covered. A description of techniques used to study magnetic materials is also presented.
Prerequisite: ENMA650.
Restriction: Permission of ENGR-Materials Science & Engineering department.

ENMA681 Diffraction Techniques in Materials Science (3 Credits)
Advanced methods of x-ray scattering/diffraction available thanks to the more powerful sources available to us. The availability of these sources enables us to study liquid crystals, polymers, nanomaterials, quasiorganized materials (including nano) and disordered materials. We will consider scattering/diffraction from the electronic level and build up to the molecular level.
Prerequisite: Permission of ENGR-Materials Science & Engineering department.

ENMA682 Electron Microscopy for Research (3 Credits)
An overview of the basic principles of operation for modern electron microscopes and how they are used in modern research. Details will be given on the construction of microscopes, their basic operation, and the types of questions that can be addressed with an electron microscope. Emphasis will be placed on a conceptual understanding of the underlying theories, and how to apply these to real-world research problems. Independent study into a specific area of electron microscopy will contribute to a term paper. Upon completion of this course, student will be expected to have a basic understanding sufficient to give interpretations of microscopy images and to suggest the correct tool or approach for certain research studies.
Restriction: Permission of ENGR-Materials Science & Engineering department.
Credit Only Granted for: ENMA682 or ENMA698J.
Formerly: ENMA698J.

ENMA683 Structural Determination Laboratory (1 Credit)
The operation of an electron microscope is covered. TEM techniques that are used to characterize the structure, defects and composition of a sample are presented and used to study a variety of materials. These techniques are: electron diffraction patterns, bright/dark field imaging, high resolution lattic imaging and energy dispersive x-ray spectroscopy. Also covers different sample preparation techniques for TEM. The goal is that the students become independent users of the TEM.
Restriction: Permission of ENGR-Materials Science & Engineering department.
Credit Only Granted for: ENMA698L or ENMA683.
Formerly: ENMA698L.

ENMA684 Advanced Finite Element Modeling (3 Credits)
A brief review of mechanical behavior of materials, introduction to Finite Element Modeling (FEM), and procedures for predicting mechanical behavior of materials by FEM using computer software (at present ANSYS). The FEM procedures include, setting up the model, mesh generation, data input and interpretation of the results.
Restriction: Permission of ENGR-Materials Science & Engineering department.
Credit Only Granted for: ENMA684 or ENMA698I.
Formerly: ENMA698I.

ENMA685 Advanced Electrical and Optical Materials (3 Credits)
Students become familiar with basic and state of the art knowledge of some technologically relevent topics in materials engineering and applied physics, including dielectric/ferroelectric materials, magnetic materials, superconductors, multiferroic materials and optical materials with an underlying emphasis on the thin film and device fabrication technology. Fundamental physical properties and descriptions of different materials and their applications are included. Discussion will include new developments in the fields.
Credit Only Granted for: ENMA685 or ENMA698F.
Formerly: ENMA698F.

ENMA687 Nanoscale Photonics and Applications (3 Credits)
Advanced topics in photonics including optical ray propogation, LEDS and the interaction of light in nanostructured materials for optoelectronic applications will be covered.
Credit Only Granted for: ENMA687 or ENMA698Z.
Formerly: ENMA698Z.

ENMA688 Seminar in Materials Science and Engineering (1 Credit)
Current research in materials science and engineering and related fields.
Restriction: Must be in Engineering: Materials Science program.
Repeatable to: 4 credits if content differs.
Formerly: ENMA697.

ENMA689 Special Topics in Engineering Materials (3 Credits)
Restriction: Permission of instructor; and permission of ENGR-Materials Science & Engineering department.
Repeatable to: 6 credits if content differs.
Formerly: ENMA691.

ENMA698 Special Problems in Materials Science and Engineering (1-3 Credits)
Individual, supervised study in materials science and engineering.
Restriction: Permission of ENGR-Materials Science & Engineering department.
Repeatable to: 6 credits if content differs.

ENMA797 Independent Study (3 Credits)
This course is designed to provide students with a directed independent study course in order to prepare the scholarly paper required for the master's degree without thesis degree option.

ENMA799 Master's Thesis Research (1-6 Credits)

ENMA808 Advanced Topics in Engineering Materials (3 Credits)
Restriction: Permission of ENGR-Materials Science & Engineering department.
Repeatable to: 6 credits if content differs.

ENMA898 Pre-Candidacy Research (1-8 Credits)

ENMA899 Doctoral Dissertation Research (1-8 Credits)