MATERIALS SCIENCE AND ENGINEERING (EG) {MSE}

099. Undergraduate Research and/or Independent Study. (C) Open to all students.

An opportunity for the student to become closely associated with a professor (1) in a research effort to develop research skills and technique and/or (2) to develop a program of independent in-depth study in a subject area in which the professor and student have a common interest. The challenge of the task undertaken must be consistent with the student's academic level. To register for this course, the student and professor jointly submit a detailed proposal to the undergraduate curriculum chairman no later than the end of the first week of the term. Note: a maximum of 2 c.u. of MSE 099 may be applied toward the B.A.S. or B.S.E. degree requirements.

215. Introduction to Nanoscale Functional Materials. (B) Prerequisite(s): MSE 220.

The purpose of this first course in the major is to introduce the student to keey concepts underlying the design, properties and processing of nanoscale functional materials, and how they are employed in practical applications. Fundamental chemical and physical principles underlying the properties of electronic, dielectric and magnetic materials will be developed in the context of metals, semiconductors, insulators, crystals, glasses, polymers and ceramics. Miniaturizaiton and the nanotechnology revolution confronts materials science with limitations and opportunities; examples in which nanoscale materials are really different from our macro world experience will be explored.

L/R 220. (BE 220) Structural and Biomatrials. (C) Prerequisite(s): Knowledge of basic calculus and chemistry.

This coure provides an introduction to the fundamental concepts of Materials Science through an examination of the structure, property, performance relationship for synthetic and biologic structural materials with a focus on surgical implants and medical devices. Consideration is given to issues of biocompatibility, degradation of materials by the biologic systems, and biologic response to artificial materials. Particular attention will be given to the materials of total hip and knew prostheses and their relationship to the long term outcomes in hip and knew arthroplasty.

L/R 221. Quantum Physics of Materials. (C) Prerequisite(s): PHYS 150, 151 concurrent and MATH 240. Meets Natural Science Requirement.

The course is directed at the development of a background in the basic physics required to understand the behavior of electrons in atoms, molecules and solids. Examples to illustrate the application of these techniques will be centered in the free and nearly free electron theory of solids. The application of modern physics to many state-of-the-art materials analysis techniques will be demonstrated thorughout the course.

L/L 250. Nano-scale Materials Lab. (B) Prerequisite(s): MSE 220.

The course provides an in-depth experimental introduction to key concepts in materials and the relationships between nanoscale structure, the properities and performance. The use of laboratory methods to examine the structure of materials, to measure the important properties, and to investigate the relationship between structure and properties is covered. Emphasis is place don a complete exposure of Nano and Materials science as a field. Most experiments require multiple laboratory sessions, with priority given to experiments in which students explore the entire range of materials science, from the synthesis of materilas and the characterization of structure, thermodynamics and composition, to the measurement of properties and discussion of applications. Students are able to realize working devices as an end product of the key laboratories in this course. Practice in oral and written communication is realized through course assignments.

260. Energetics of Macro and Nano-scale Materials. (B) Prerequisite(s): CHEM 101 or 102.

Basic principles of chemical thermodynamics as applied to macro and nano-sized materials. This course will cover the fundamentals of classical thermodynamics as applied to the calculation and predictionof phase stability, chemcial reactivity and synthesis of materials systems. The size-dependent properties of nano-sized systems will be explored through the incorporation of the thermodynamic properties of surfaces. The prediciton of the phase stability of two and three component systems will be illustrated through the calculation and interpretation of phase diagrams for metallic, semiconductor, inorganic, polymeric and surfactant systems.

330. (BE 330) Soft Materials: Colloids, Polymers, Gels and Crystals. Faculty. Prerequisite(s): CHEM 102 ; MSE 220 (Intro. to Materials) or equivalent (Concurrent is OK).

Soft matter describes materials that are neither pure crystalline solids with long range atomic order or pure liquids characterized by one simple viscosity. Many times soft materials display both solid and liquid like behavior depending on the timescale of the applied stress. Colloids, polymers, amphiphiles, liquid crystals, and biomacromolecules are types of soft matter. The focus of this course is on the characteristics common to soft materials namely their length scale, fragile binding energies or proximity to phase transitions, dynamics and propensity to self-assemble.

360. Structure of Materials. (A) Prerequisite(s): MSE 260.

Basic principles of material structure and organization from nano to macro sizes. This course will cover the fundamentals of materials structure including the crystalline, liquid crystalline and glassy states as well as 1-D, 2-D and 3-D structure and defects. Examples will be used fromt he different classes of materials - metallic, semiconductor, inorganic, polymeric - with particular emphasis on important components of structure on the nanoscale including particles, surfaces, interaces and defects.

393. Materials Selection. (B) Prerequisite(s): MSE 220, Junior or Senior Standing.

Throughout mankind's history, materials have played a critical role in civilization and technology. The selection of materials has been based on availability and functionality. The rapid advances of materials technologies in the last 150 years, however, have made nearly all classes and forms of materials available, at a cost. Therefore, in theory at least, materials selection can now proceed on a rational basis as an optimization process. In this course, we will focus on two major areas of materials applications in modern world, structural applications where mechanical design is central and electronic applications where system functionality is the driver, to examine the validity of the above proposition, sometimes reaching surprising conclusions. Issues of process integration in material selection, which feature especially prominently in electronic materials with continuing trend toward miniaturization (now down to 90 nm in commercial products), are emphasized. Emerging bionic applications and historical trends will also be examined in student projects and assigned readings. By the end of the course, the students can expect to acquire a level of engineering familiarity with a broad range of materials, and be prepared to undertake material design projectsin the future.

405. (MEAM405, MEAM505, MSE 505) Mechanical Properties of Macro/Nanoscale Materials. (A)

The application of continuum and microstructural concepts to consideration of the mechanics and mechanisms of flow and fracture in metals, polymers and ceramics. The course includes a review of tensors and elasticity with special emphasis on the effects of symmetry on tensor properties. Then deformation, fracture and degradation (fatique and wear) are treated, including mapping strategies for understanding the ranges of material properties.

422. Electronic Materials II. (C)

430. (CBE 430, CBE 510, MSE 580) Polymers and Biomaterials. (B) Prerequisite(s): MSE 260 or equivalent course in thermodynamics or physical chemistry (such as BE 223, CHE 231, CHEM 221, MEAM 203).

This course focuses on synthesis, characterization, microstructure, rheology, and structure-property relationships of polymers, polymer directed composites and their applications in biotechnology. Topical coverage includes: polymer synthesis and functionalizaiton; polymerizaiton kinetics; structure of glassy, crystalline, and rubbery polymers; thermodynamics of polymer solutions and blends, and crystallization; liquid crystallinity, microphase separation in block copolymers; polymer directed self-assembly of inorganic materials; biological applications of polymeric materials. Case studies include thermodynamics of block copolymer thin films and their applications in nanolithography, molecular templating of sol-gel growth using block copolymers as templates; structure-property of conducting and optically active polymers; polymer degradation in drug delivery; cell adhesion on polymer surface in tissue engineering.

440. (MSE 540) Phase Transformations. (B)

The state of matter is dependent upon temperature, thermal history, and other variables. In this course the science of structural transitions is treated, with the purpose in mind of utilizing them for producing materials with superior properties. The subjects covered include the methods of structural analysis, solidification, solid state transformation, and order-disorder transition.

455. (MSE 555) Environmental Degradation. (B) Prerequisite(s): MSE 220 or permission of the instructor.

This course is designed to provide an understanding of the corrosion principles and the engineering methods used to minimize and prevent corrosion. Metals and alloys are emphasized because these are the materials in which corrosion is the most prevalent. Aqueous environments are also emphasized these are the common corrosion conditions.

In the first half of the course, the impact and electrochemical nature of corroare described, and then the corrosion fundamentals (electrochemical reactions, phase (pourbaix) diagrams, aqueous corrosion kinetics, passivity, and high-temperature oxidation) are emphasized. The forms of corrosion (galvanic, pitting and crevice, environmentally induced cracking) and corrosio in the human body (for example, surgical implants and prosthetic devices) and in other selective environments (concrete, seawater, and water solutions conta dissolved salts, sulfur, and bacteria) are also described in the second half. Corrosion in the human body (for example, surgical implants and prosthetic devices) and in othr selective environments (concrete, scawater, and water solutions containing dessolved salts, sulfur, and bacteria) are also described in the second half.

465. (MSE 565) Fabrication and Characterization of Nanostructured Devices.

This course surveys various processes that are used to produce materials structured at the micron and nanometer scales for electronic, optical and chemical applications. Basic principles of chemistry, physics, thermodynamics and kinetics are applied to solid state, liquid, and colloidal approaches to making materials. The newest approaches to nanofabrication: microcontact printing, self-assembly, and Nanolithography, are covered. The course is heavily lab based, with 25% of class time and 30% of the homework devoted to hands on experiences. Lab assignments are a series of structured group projects. Evaluation is based on 3-4 lab reports, 4-5 problem sets, and 4-5 journal paper summaries.

495. Senior Design. (A)

Independent student or team research on the design and construction of an original experimental or theoretical project related to materials science. The results of this project are presented at the end of the year in the form of a thesis and in an oral presentation to peers and faculty.

496. Senior Design. (B)

Independent student or team research on the design and construction of an original experimental or theoretical project related to materials science. The results of this project are presented at the end of the year in the form of a thesis and in an oral presentation to peers and faculty.

500. Experimental Methods in Materials Science. (M) Fischer. Prerequisite(s): Permission of the Undergraduate Curriculum Chair and Instructor.

Laboratory course covering many of the experiemental techniques used in materials science: optical and electron microscopy, mechanical testing, x-ray diffraction, electrical and optical measurements, superconducting and magnetic properties, solid-state diffusion.

505. (MEAM405, MEAM505, MSE 405) Mechanical Properties of Macro/Nanoscale Materials. (A)

The application of continuum and microstructural concepts to consideration of the mechanics and mechanisms of flow and fracture in metals, polymers and ceramics. The course includes a review of tensors and elasticity with special emphasis on the effects of symmetry on tensor properties. Then deformation, fracture and degradation (fatique and wear) are treated, including mapping strategies for understanding the ranges of material properties.

520. Structure of Materials. (A) Prerequisite(s): Permission of the Undergraduate Curriculum Chair and Instructor.

Description of Crystal Structure-Symmetry, Point and Space Groups. Structures of different material types-glasses, polymers, semiconductors, ceramics and metals. Relationship between bonding and structural types. Methods of structure determination. Diffraction of x-rays and neutrons--x-ray methods. Microstructures of solids. Topology of granular structures. Grain boundary structures. Fractal description of microstructures.

530. Thermodynamics and Phase Equilibria. (A) Worrell, Winey. Prerequisite(s): Permission of the Undergraduate Curriculum Chair and Instructor.

Review of fundamental thermodynamic laws and criteria for equilibrium. Reaction equilibria in multicomponent systems. Free energies of mixing solutions, liquids, solids, and polymers. Binary and ternary phase diagrams. Surfaces and interfaces.

537. (MEAM537) Nanomechanics and Nanotribology at Interfaces. (C) Faculty. Prerequisite(s): Freshman physics; MEAM 354 or equivalent, or consent of instructor.

Engineering is progressing to ever smaller scales, enabling new technologies, materials, devices, and applications. Mechanics enters a new regime where the role of surfaces, interfaces, defects, material property variations, and quantum effects play more dominant roles. This course will provide an introduction to nano-scale mechanics and tribology at interfaces, and the critical role these topics play in the developing area of nanoscience and nanotechnology. We will discuss how mechanics and tribology at interfaces become integrated with the fields of materials science, chemistry, physics, and biology at this scale. We will cover a variety of concepts and applications, drawing connections to both established and new approaches. We will discuss the limits of continuum mechanics and present newly developed theories and experiments tailored to describe micro- and nano-scale phenomena. We will emphasize specific applications throughout the course. Literature reviews, critical peer discussion, individual and team problem assignments, a laboratory project, and student presentations will be assigned as part of the course.

540. (MSE 440) Phase Transformations. (B) Chen. Prerequisite(s): Permission of the Undergraduate Curriculum Chair and Instructor.

The atomic structure of condensed matter is dependent upon temperature, pressure, thermal history and other variables. In this course, the science of such structural transitions is treated. The topics discussed include introduction to statistical mechanics, theory of nucleation and growth kinetics, solidification, diffusionless solid state transformations, and microscopic theory of phase transition.

550. (MEAM519, MSE 420) Mechanical Properties of Nano and Macro-Scale Materials. (A) Vitek. Prerequisite(s): Permission of the Undergraduate Curriculum Chair and Instructor.

Elastic and plastic behavior of materials. Stress, strain, anisotropic Hook's law, equations of elasticity; solution of selected stress distribution problems plane elasticity. Yield criteria. Fracture criteria. Microscopic mechanisms of plasticity and fracture, dislocation theory.

555. (MSE 455) Environmental Degradation. (A)

This course is designed to provide an understanding of the corrosion principles and the engineering methods used to minimize and prevent corrosion. Metals and alloys are emphasized because these are the materials in which corrosion is the most prevalent. Aqueous environments are also emphasized these are the common corrosion conditions.

In the first half of the course, the impact and electrochemical nature of corroare described, and then the corrosion fundamentals (electrochemical reactions, phase (pourbaix) diagrams, aqueous corrosion kinetics, passivity, and high-temperature oxidation) are emphasized. The forms of corrosion (galvanic, pitting and crevice, environmentally induced cracking) and corrosio in the human body (for example, surgical implants and prosthetic devices) and in other selective environments (concrete, seawater, and water solutions conta dissolved salts, sulfur, and bacteria) are also described in the second half

561. (MEAM660) Atom Mod in Mats Science. (C)

565. (MSE 465) Fabrication and Characterization of Nanostructured Devices. (M) Bonnell. Prerequisite(s): MSE 360 or MSE 560.

This course will focus on the processing of inorganic materials used as ceramics. The physical interactions in processes specific to the formation of ceramics are examined; e.g., fractionation, disperison forces in compacts, sintering, etc. Structure and properties of amorphous oxides and devitrification to form glass ceramics will be discussed.

566. Physical Properties of Ceramics. (A) Prerequisite(s): MSE 360 or MSE 560 and a good foundation in solid state physics are prerequisites for this class.

This course will focus on the properties of inorganic compounds considered to be ceramics. Optical, dielectric and magnetic properties of oxides are treated in depth and illustrated with laboratory demonstrations and experiments. Strategies for mechanical property optimization are examined.

570. (ESE 514) Physics of Materials I. (C) Fischer. Prerequisite(s): Undergraduate physics and math thru modern physics and differential equations.

Failures of classical physics and the historical basis for quantum theory. Postulates of wave mechanics; uncertainty principle, wave packets and wave-particle duality. Schrodinger equation and operators; eigenvalue problems in 1 and 3 dimensions (barriers, wells, hydrogen, atom). Perturbation theory; scattering of particles and light. Free electron theory of metals; Drude and Sommerfeld models, dispersion relations and optical properties of solids. Extensive use of computer-aided self-study will be made.

571. (ESE 515) Physics of Materials II. (M) Fischer. Prerequisite(s): MSE 570 or equivalent.

Failures of free electron theory. Crystals and the reciprocal lattice wave propagation in periodic media; Bloch's theorem. One-electron band structure models: nearly free electrons, tight binding. Semiclassical dynamics and transport. Cohesive energy, lattic dynamic and phonons. Dielectric properties of insulators. Homeogenous semiconductors and p-n junctions. Experimental probes of solid state phenomena; photoemission, energy loss spectroscopy, neturon scattering. As time permits, special topics selected from the following: correlation effects, semiconductor alloys and heterostructures, amorphous semiconductors, electro-active polymers.

575. Statistical Mechanics. (C)

580. (MSE 430) Polymers and Biomaterials. (B) Prerequisite(s): MSE 260 or equivalent course in thermodynamics or physical chemistry (such as BE 223, CHE 231, MEAM 203).

This course focuses on synthesis, characterization, microstructure, rheology, and structure-property relationships of polymers, polymer directed composites and their applications in biotechnology. Topical coverage includes: polymer synthesis and functionalizaiton; polymerizaiton kinetics; structure of glassy, crystalline, and rubbery polymers; thermodynamics of polymer solutions and blends, and crystallization; liquid crystallinity, microphase separation in block copolymers; polymer directed self-assembly of inorganic materials; biological applications of polymeric materials. Case studies include thermodynamics of block copolymer thin films and their applications in nanolithography, molecular templating of sol-gel growth using block copolymers as templates; structure-property of conducting and optically active polymers; polymer degradation in drug delivery; cell adhesion on polymer surface in tissue engineering.

581. Advanced Polymer Physics. (A) Winey/Composto. Prerequisite(s): MSE 430 or equivalent.

Advanced polymer physics includes the topics of polymer chain statistics, thermodynamics, rubber elasticity, polymer morphology, fracture, and chain relaxation. Rigorous derivations of select theories will be presented along with experimental results for comparison. Special topics, such as liquid crystalline polymers, blends and copolymers, will be presented throughout the course. Special topics, such as liquid crystallintiy, nanostructures, and biopolymer diffusion, will be investigated by teams of students using the current literature as a resource.

590. Surface and Thin Film Analysis Techniques. (B) Bonnell, Composto.

The objective of this course is to study the fundamental physics of the interaction of ions, electrons, photons, and neutrons with matter. A second objective is to use the products of these interactions to characterize the atomic (or molecular) structure, composition, and defects of a semiconductor, ceramic, polymer, composite, or metal. Ion beam techniques will include Rutherford backscattering and forward recoil spectrometry, and secondary ion mass pectrometry. Electron probe techniques will include x-ray photoelectron spectroscopy. Neutron techniques will include neutron reflectivity. The strengths and weaknesses of each technique will be discussed. Examples will be drawn from metallurgy, electronic materials, polymer science, ceramic science, archaeology, and biology.

610. Electron Microscopy. (B) Luzzi.

Theoretical and practical aspects of conventional and high-resolution transmission electron microscopy and related techniques. Imaging theory; kinematical and dynamical diffraction theory. Diffraction contrast analysis of imperfect crystals; phase contrast analysis of crystal lattice structures. With laboratory.

650. Micromechanisms of Deformation and Fracture. (M) Laird. Prerequisite(s): Permission of the Undergraduate Curriculum Chair and Instructor.

Basic mechanisms of deformation and fracture, theory of dislocations (continuum theory and effects of the atomic structure), deformation properties of different crystal structures (fcc, bcc, hcp, ordered alloys, amorphous materials), hardening mechanisms (solid solution and dispersion hardening), creep deformation and fracture at high temperatures, micromechanisms of fracture.

670. Statistical Mechanics of Solids. (A)

This course constitutes an introduction to statistical mechanics with an emphasis on application to crystalline solids. Ensemble theory, time and ensemble averages and particle statistics are developed to give the basis of statistical thermodynamics. The theory of the thermodynamic properties of solids is presented in the harmonic approximation anharmonic properties are treated by the Mie-Gruneisen method. Free electron theory in metals and semiconductors is given in some detail, with the transport properties being based on conditional transition probabilities and the Boltzmann transport equation. The theory of order-disorder alloys is treated by the Bragg-Williams, Kirkwood and quasi-chemical methods.

790. Selected Topics in Materials Science and Engineering. (C) Staff. Both terms.

Students should check department office for special topics.

895. Teaching Practicum. (C)