Materials Science and Engineering

Materials Science and Engineering, MTSE

MTSE 5000. Thermodynamics of Materials. 3 hours. The zeroth law of thermodynamics, work, energy and the first law of thermodynamics; the second law of thermodynamics, thermodynamic potentials, the third law of thermodynamics, thermodynamic identities and their uses, phase equilibria in one-component systems, behavior and reactions of gases. Solutions, binary and multicomponent systems: phase equilibria, materials separation and purification. Electrochemistry. Thermodynamics of modern materials including liquid crystals.

MTSE 5010. Bonding, Structure and Crystallography. 3 hours. Interatomic bonding; amorphous and crystalline structures in metals, ceramics and polymers; point and line defects in crystals; structure determination by X-ray diffraction; basic symmetry operations, point and space groups in crystal systems. Prerequisite(s): ENGR 3450.

MTSE 5020. Mechanical Properties of Materials. 3 hours. Stress, strain and the basics of concepts in deformation and fracture for metals, polymers and ceramics. Analysis of important mechanical properties such as plastic flow, creep, fatigue, fracture toughness, and rupture. Application of these principles to the design of improved materials and engineering structures.

MTSE 5030. Transport Phenomena and Materials Processing. 3 hours. Principles of transport phenomena (momentum, heat, and mass transport) in materials processes. Emphasis on applications of appropriate differential equations and boundary conditions to solve materials processing problems. Prerequisite(s): MTSE 5000 and MTSE 5010 or consent of instructor.

MTSE 5070. Tribology of Materials. 3 hours. Contact mechanisms of surfaces. Friction, wear and lubrication of solids and liquids. Laboratory equipment used in tribological investigations. Theoretical and empirical models of tribology.

MTSE 5100. Fundamental Concepts of Materials Science. 3 hours. Crystal structures including defects and structures of non-crystalline materials. Phase diagrams, intermolecular forces. Organic raw materials, metals and alloys, ceramics, electronic materials, liquid crystals, polymers, natural and synthetic composites, smart materials, hybrids. Mechanical, thermophysical, electrical, magnetic and surface properties including tribology, corrosion and degradation. Testing of materials. Prerequisite(s): consent of department.

MTSE 5200. Advanced Concepts of Metallurgical Science. 3 hours. Chemical and physical properties of metals and alloys. Emphasis on the relationship of structure and thermodynamics to behavior. Topics include crystal structure, thermodynamics, phase diagrams, phase transformations, oxidation, mechanical, electrical and magnetic properties. Prerequisite(s): PHYS 4110, CHEM 3510 or consent of department.

MTSE 5210. Corrosion and Oxidation of Materials. 3 hours. Electrochemical corrosion mechanisms, corrosion prevention and high temperature corrosion. Oxidation mechanisms of metals and alloys, internal oxidation, oxidation resistant alloys and other methods of oxidation protection. Prerequisite(s): MTSE 5200 or consent of department.

MTSE 5300. Science and Technology of Modern Ceramics. 3 hours. Emphasis on structure-property relationships: chemical bonding, crystal structures, crystal chemistry, electrical properties, thermal behavior, defect chemistry. Processing topics: powder preparation, sol-gel synthesis, densification, toughening mechanisms. Materials topics: glasses, dielectrics, superconductors, aerogels. Prerequisite(s): MTSE 5100, MTSE 5200 or consent of department.

MTSE 5310. Sol-Gel Processing. 3 hours. Elements of sol-gel synthesis and processing, including colloids, sols, alkoxide chemistry, hydrolysis and condensation reactions, gelation mechanisms, novel synthesis methods, sol-gel thin films, thin film processing and characterization of sol-gel products. Prerequisite(s): MTSE 5300 or consent of department.

MTSE 5400. Advanced Polymer Physics and Chemistry. 3 hours. Chemical structures, polymerization, molar masses, chain conformations. Rubber elasticity, polymer solutions, glassy state and aging. Mechanical properties, fracture mechanics and viscoelasticity. Dielectric properties. Polymer liquid crystals. Semi-crystalline polymers, polymer melts, rheology and processing. Thermal analysis, microscopy, diffractometry and spectroscopy of polymers. Computer simulations of polymer-based materials.

MTSE 5410. Polymer Reliability. 3 hours. Reliability of polymers and polymer-based composites (PPCS); flexible, semirigid, rigid, elastromeric, crosslinked polymers, heterogeneous polymer-containing (such as polymer + ceramic) composites and polymer liquid crystals. Prediction of long-term performance from short-term tests. Prerequisite(s): MTSE 5400 or consent of department.

MTSE 5415. Polymer Viscoelasticity. 3 hours. Polymer structure-property relations, linear and nonlinear viscoelasticity, dynamic mechanical analysis, time temperature superposition, creep and stress relaxation, mechanical models for prediction of polymer deformation, rubber elasticity, environmental effects on polymer deformation, instrumentation for prediction of long term properties. Prerequisite(s): MTSE 5400.

MTSE 5430. Polymer Rheology and Processing. 3 hours. Experimental methods for viscosity-temperature-shear rate measurements, application to melts, filled systems and suspensions. Injection, extrusion, thermoforming, blow molding, rotational molding, compression and transfer molding, calendaring and post-manufacturing operations. Prerequisite(s): MTSE 5400 or consent of department.

MTSE 5440. Thermal Analysis. 3 hours. Differential scanning calorimetry; thermogranvimetric metric analysis; dynamic mechanical and thermomechanical analysis; glass transition; melting transitions, relaxations in the glassy state, liquid crystalline phase changes. Prerequisite(s): MTSE 5400 or consent of department.

MTSE 5500. Electronic, Optical and Magnetic Materials. 3 hours. Intensive study of the properties of electronic, optical and magnetic materials. Electrical and thermal conduction, elementary quantum physics, bonding, band theory, semi-conductors, dielectrics, magnetic properties, superconductivity, optical properties. Prerequisite(s): PHYS 4500 or consent of department.

MTSE 5515. Materials and Solid State Devices. 3 hours. How electronic, optical and magnetic devices actually work based on a materials perspective. P-N junctions, MOS capacitors, mosfets, CMOS, Bi-CMOS, RF, MRAM and optical detectors/switches; emphasis on the importance of mastering materials properties in electrical engineering device design and integration. Prerequisite(s): MTSE 5500 or consent of department.

MTSE 5520. Physical and Chemical Basis of Integrated Circuit Fabrication. 3 hours. Current requirements and future trends in processing technology for very large scale integrated circuits and related application. Wafer fabrication, lithography, oxidation, diffusion, ion implantation, film deposition, wet and dry etching, multilevel metal interconnect, process integration and process simulation. Prerequisite(s): MTSE 5500 or consent of department.

MTSE 5530. Integrated Circuit Packaging. 3 hours. Basic packaging concepts, materials, fabrication, testing and reliability, as well as the basics of electrical, thermal and mechanical considerations as required for the design and manufacturing of microelectronics packaging. Current requirements and future trends are presented. General review of analytical techniques used in the evaluation and failure analysis of microelectronic packages. Prerequisite(s): MTSE 5500 or consent of department.

MTSE 5540. Materials for Advanced Displays. 3 hours. Materials and processing requirements for new display concepts including field emission displays, organic light emitting displays, flexible displays, laser-based displays and inorganic electroluminescent displays. Special emphasis will be placed on the materials effects on device reliability. Prerequisite(s): MTSE 5500 or consent of department.

MTSE 5550. Materials and Mechanics for MEMS Devices. 3 hours. Methods, techniques and philosophies used to characterize MEMS structures for engineering applications. Topics include fundamentals of elastic and plastic deformation in microscale, anisotropic material properties, crystalline and non-crystalline materials, and mechanical behavior such as strength, fracture, creep and fatigue as they relate to the microscale design. Material characterization, mechanical testing and mechanical characterization are discussed. Emphasis is on emerging techniques to assess design-relevant mechanical properties. Prerequisite(s): consent of department.

MTSE 5560. Compound Semiconductor Materials and Devices. 3 hours. Introduction to compound semiconductors; epitaxial growth and electronic properties of heterojunctions (ideal single heterojunctions: isotype and anisotype; non-ideal heterojunctions; and heterojunctions); applications of heterostructures (heterojunction bipolar transistors, modulation-doped field-effects transistors, LEDS, double heterojunction lasers, photodiodes and photoconductors). Prerequisite(s): MTSE 5500 or consent of instructor.

MTSE 5570. Vacuum Technology and Thin Films. 3 hours. Introduction and basics of kinetic theory, UHV hardware overview and practical system design; introduction to surface physics, thermodynamics versus kinetics of surfaces, growth modes and nucleation barriers. Prerequisite(s): MTSE 5500 or consent of instructor.

MTSE 5580. Materials for a Sustainable Environment. 3 hours. Properties of renewable and nonrenewable, sustainable and non-sustainable materials; effects of product application and needs on material choices for a sustainable environment; degradation mechanisms and influence of the environment on mechanisms. Prerequisite(s): consent of department.

MTSE 5600. Materials Characterization. 3 hours. Survey of atomic and structural analysis techniques as applied to surface and bulk materials. Physical processes involved in the interaction of ions, electrons and photons with solids; characteristics of the emergent radiation in relation to the structure and composition. Prerequisite(s): MTSE 5200, MTSE 5300, MTSE 5400 or consent of department.

MTSE 5610. Fundamentals of Surface and Thin Film Analysis. 3 hours. Survey of materials characterization techniques; optical microscopy; Rutherford backscattering; secondary ion mass spectroscopy; ion channeling; scanning tunneling microscopy; x-ray photoelectron spectroscopies; surface properties. Prerequisite(s): MTSE 5600 or consent of department.

MTSE 5620. Scanning Electron and Ion Microscopy. 3 hours. Theory and applications of scanning electron microscopy and focused ion beam instrumentation. Topics include electron-solid and ion-solid interactions, electron and ion optics, image formation and analysis, X-ray microanalysis, electron backscattered diffraction analysis, focused ion beam patterning and deposition, and specimen preparation. Prerequisite(s): MTSE 5500, PHYS 2220 or equivalent, and consent of instructor.

MTSE 5625. Scanning Electron and Microscopy Laboratory. 1 hour. Students gain hands-on experience with the SEM, FESEM, FIB, EDS, EDSD and sample preparation equipment. Closely follows the MTSE 5620 lecture course, and concurrent enrollment in both courses is strongly recommended. Prerequisite(s): MTSE 5500, PHYS 2220 or equivalent, and consent of instructor. MTSE 5620 must be completed prior to or concurrently with this laboratory.

MTSE 5700. Seminar in Materials Science and Engineering. 1–3 hours. Current topics in materials science and engineering.

MTSE 5710. Computational Materials Science. 3 hours. Focus on the use of computational modeling to understand and evaluate the behavior and materials at scales from the atomistic to the continuum. Introduction to the basic principles used to simulate, model and visualize structures and properties of materials. Topics include the various methods used at different length and time scales ranging from the atomistic to the microscopic. Prerequisite(s): MTSE 5000, MTSE 5010 and MTSE 6000.

MTSE 5800-MTSE 5810. Special Studies in Materials Science. 3 hours each. Organized classes specifically designed to accommodate the needs of students and the demands of program development that are not met by regular offerings. Short courses and workshops on specific topics, organized on a limited-offering basis, to be repeated only upon demand. May be repeated for credit.

MTSE 5820. Internship in Materials Science. 3 hours. A supervised industrial internship requiring a minimum of 150 clock hours of work experience. Prerequisite(s): consent of department.

MTSE 5830. Cooperative Education in Materials Science. 3 hours. Supervised work in a job directly related to the student's major, professional field of study or career objective.

MTSE 5900-MTSE 5910. Special Problems in Materials Research. 1–6 hours each. Special problems in advanced materials science for graduate students. Problems chosen by the student with approval of the supervising professor and the department chair.

MTSE 5920-MTSE 5930. Research Problems in Lieu of Thesis. 3 hours each. An introduction to research; may consist of an experimental, theoretical or review topic.

MTSE 5940. Seminar in Current Materials Science Literature. 1–3 hours. Reports and discussion of current materials science research published in journals and other means of dissemination of research.

MTSE 5950. Master's Thesis. 3 or 6 hours. To be scheduled only with consent of department, 6 hours of credit required. No credit assigned until thesis has been completed and filed with the graduate dean. Continuous enrollment required once work on thesis has begun. May be repeated for credit.

MTSE 5960. Materials Science Institute. 1–6 hours. For students accepted by the university as participants in special institute programs. May be repeated for credit, not to exceed a total of 6 hours in each course. Laboratory fee required.

MTSE 6000. Quantum Mechanics for Materials Scientists. 3 hours. The Schrödinger equation, atomic theory, solid state theory, band structure, tunneling and scattering with an emphasis on materials properties. Prerequisite(s): MTSE 5500 or consent of department.

MTSE 6110. Applied Fracture Mechanics. 3 hours. Linear elastic fracture mechanics, elastic-plastic fracture mechanics, time dependent failure, creep and fatigue, experimental analysis of fracture and failure of metals, ceramics, polymers and composites. Failure analysis related to material, product design, manufacturing and product. Prerequisite(s): MTSE 6100 or consent of department.

MTSE 6120. Composite Material. 3 hours. Fibers; matrix materials; interfaces; polymer matrix composites; metal matrix composites; ceramic matrix composites; carbon fiber composites; micromechanics, macromechanics, laminate theory and application, design, failure analysis. Prerequisite(s): MTSE 6100 or consent of department.

MTSE 6200. Imperfections in Solids. 3 hours. Point defects in semiconductors, metals, ceramics and non-ideal defect structures; non-equilibrium conditions produced by irradiation or quenching; effects or defects on electrical and physical properties, effects of defects at interfaces between differing materials. Prerequisite(s): MTSE 5500 or consent of department.

MTSE 6210. Deformation Mechanisms in Solid Materials. 3 hours. Discussions on microelasticity and microplasticity of materials. Application of dislocation theory to understand deformation mechanisms related to strengthening. Interactions of dislocation with solute precipitates, dispersoid, grain boundary and barriers are presented. Deformation mechanisms in amorphous and polymeric materials. Micromechanisms of deformation in fatigue, creep, creep-fatigue and strain-rate loading are described.

MTSE 6300. Phase Transformations. 3 hours. Thermodynamics, kinetic and structural aspects of metallic and ceramic phase transformations; mechanisms and rate-determining factors in solid-phase reactions; diffusion processes, nucleation theory, precipitations from solid solution, order-disorder phenomena and applications of binary and ternary phase diagrams. Prerequisite(s): MTSE 5300 or consent of department.

MTSE 6400. Advanced Electron Microscopy. 3 hours. Theory and applications of scanning and transmission electron microscopy; sample preparation and analytical techniques. Prerequisite(s): MTSE 5600 or consent of department.

MTSE 6600. Transmission Electron Microscopy. 3 hours. Theory and applications of transmission electron microscopy. Topics include electron-solid interactions, electron optics, image formation and analysis, electron diffraction, defect analysis, X-ray microanalysis, electron energy loss spectroscopy, energy filtered imaging, scanning transmission electron microscopy, Z-contrast imaging, and specimen preparation. Prerequisite(s): MTSE 5620.

MTSE 6605. Transmission Electron Microscopy Laboratory. 1 hour. Students gain hands-on experience in TEM, electron diffraction, EDS, STEM, and sample preparation equipment. Closely follows the MTSE 6600 lecture course, and concurrent enrollment in both courses is strongly recommended. Prerequisite(s): MTSE 5620. MTSE 6600 must be completed prior to or concurrently with this laboratory.

MTSE 6610. Diffraction Science. 3 hours. Diffraction theory; scattering and diffraction experiments; kinematic theory; dynamical theory; x-ray topography; crystal structure analysis; disordered crystals; quasi-crystals. Prerequisite(s): MTSE 5600, MTSE 5610 or consent of department.

MTSE 6620. Advanced Electron and Ion Microscopy. 2 hours. Gives students with existing electron and ion microscopy backgrounds the opportunity to gain theoretical and practical knowledge of advanced analytical techniques. Specific advanced topics include focused ion beam specimen preparation and patterning, Z-contrast scanning transmission electron microscopy, advanced diffraction and defect analysis, electron energy loss spectroscopy and energy filtered imaging in the transmission electron microscope, high resolution transmission electron microscopy imaging and 3D imaging of nanostructures using focused ion beam and tilt-series transmission electron microscopy. Specific applications of these techniques to modern problems in materials science are stressed. Prerequisite(s): MTSE 6600 and MTSE 6605.

MTSE 6625. Advanced Electron and Ion Microscopy Laboratory. 1 hour. Gives students with existing electron and ion microscopy backgrounds the opportunity to gain hands-on knowledge of advanced analytical microscopy techniques. Specific advanced topics include focused ion beam specimen preparation and patterning, Z-contrast scanning transmission electron microscopy, advanced diffraction and defect analysis, electron energy loss spectroscopy and energy filtered imaging in the transmission electron microscope, high resolution transmission electron microscopy imaging and 3D imaging of nanostructures using focused ion beam and tilt-series transmission electron microscopy. Specific applications of these techniques to modern problems in materials science are stressed. Prerequisite(s): MTSE 6600 and MTSE 6605. MTSE 6620 must be completed prior to or concurrently with this laboratory.

MTSE 6800. Selected Topics in Materials Science. 3 hours. Topics from specialized areas of materials science, physics and chemistry. May be repeated for credit as topics vary.

MTSE 6900-MTSE 6910. Special Problems. 1–3 hours each. Special problems in experimental or theoretical for advanced materials science graduate students. Problem chosen by the student with the approval of the supervising professor.

MTSE 6940. Individual Research. 1–3 hours. To be scheduled by the doctoral candidate engaged in research. May be repeated for credit.

MTSE 6950. Doctoral Dissertation. 3, 6 or 9 hours. To be scheduled only with consent of department. 12 hours credit required. No credit assigned until dissertation has been completed and filed with the graduate dean. Doctoral students must maintain continuous enrollment in this course subsequent to passing qualifying examination for admission to candidacy. May be repeated for credit.

MTSE 6970. Seminar for Doctoral Candidates. 3 hours. Demonstration of competence in a specific area of materials science as evidenced by criteria established by the faculty of each discipline. May be repeated for credit.

MTSE 6990. Postdoctoral Research. 3 hours. For postdoctoral fellows to further training and research experience in developing and solving problems independently. Prerequisite(s): consent of department. May be repeated for credit.

Mathematics

The content of courses will vary from time to time, reflecting current trends and recent developments.

Mathematics, MATH

MATH 5000. Instructional Issues for the Professional Mathematician. 3 hours. Focus on various instructional issues from the perspective of the professional mathematician. Some major topics include course planning, the content of a course syllabus, lecture styles, the preparation and mechanics of lectures, the conduct of problem solving sessions, classroom management, the student-instructor relationship, examination formats, the preparation, administration and grading of examinations and the management of teaching assistants and graders. Prerequisite(s): consent of department.

MATH 5010-MATH 5020. Mathematical Logic and Set Theory. 3 hours each. Rigorous development of first-order logic, basic model theory, completeness and incompleteness theorems, decidable and undecidable theories, axioms of set theory, ordinal and cardinal numbers, the axiom of choice, the continuum hypothesis, constructible sets, and basic descriptive set theory.

MATH 5050. Linear Programming. 3 hours. Convex polyhedra, simplex method, duality theory, network flows, integer programming, ellipsoidal method, applications to modeling and game theory. Prerequisite(s): consent of department.

MATH 5110-MATH 5120. Introduction to Analysis. 3 hours each. A rigorous development for the real case of the theories of continuous functions, differentiation, Riemann integration, infinite sequences and series, uniform convergence and related topics; an introduction to the complex case.

MATH 5200. Topics in Dynamical Systems. 3 hours. Dynamical systems in one and higher dimensions. Linearization of hyperbolic fixed points. Hamiltonian systems and twist maps. The concept of topological conjugacy and structural stability. Anosov diffeomorphisms, geodesic flow and attractors. Chaotic long-term behavior of these hyperbolic systems. Measures of complexity. Prerequisite(s): consent of department.

MATH 5210-MATH 5220. Numerical Analysis. 3 hours each. A rigorous mathematical analysis of numerical methods: norms, error analysis, linear systems, eigenvalues and eigenvectors, iterative methods of solving non-linear systems, polynomial and spline approximation, numerical differentiation and integration, numerical solution or ordinary and partial differential equations. Prerequisite(s): FORTRAN programming or consent of department.

MATH 5290. Numerical Methods. 3 hours. A non-theoretical development of various numerical methods for use with a computer to solve equations, solve linear and non-linear systems of equations, find eigenvalues and eigenvectors, approximate functions, approximate derivatives and definite integrals, solve differential equations and solve other such problems of a mathematical nature. Errors due to instability of method and those due to the finite-precision computer will be studied. Prerequisite(s): a programming language and consent of department.

MATH 5310-MATH 5320. Functions of a Real Variable. 3 hours each.

MATH 5310. Sets and operations; descriptive set properties; cardinal numbers; order types and ordinals; metric spaces; the theory of Lebesque measure; metric properties of sets.

MATH 5320. Set functions and abstract measure; measurable functions; types of continuity; classification of functions; the Lebesque integral; Dini derivatives and the fundamental theorem of the calculus.

MATH 5350. Markov Processes. 3 hours. The ergodic theorem; regular and ergodic Markov chains; absorbing chains and random walks; mean first passage time; applications to electric circuits, entropy, genetics, games, decision theory and probability.

MATH 5400. Introduction to Functions of a Complex Variable. 3 hours. Algebra of complex numbers and geometric representation; analytical functions; elementary functions and mapping; real-line integrals; complex integration; power series; residues, poles, conformal mapping and applications. Only one course, MATH 5400, MATH 5500 or MATH 5600, may be used towards satisfying the course work requirements for a graduate degree in mathematics.

MATH 5410-MATH 5420. Functions of a Complex Variable. 3 hours each. The theory of analytic functions from the Cauchy-Riemann and Weierstrass points of view.

MATH 5450. Calculus on Manifolds. 3 hours. Introduction to differential geometry and topology. Topics include implicit and inverse function theorems, differentiable manifolds, tangent bundles, Riemannian manifolds, tensors, curvature, differential forms, integration on manifolds and Stokes' theorem. Prerequisite(s): consent of department.