Materials Sciences and Engineering

MSEN 5300 (MECH 5300 and PHYS 5376) Introduction to Materials Science (3 semester credit hours) This course provides an extensive overview of materials science and engineering and includes the foundations required for further graduate study in the field. Topics include chemical bonding, crystalline structures, imperfections and diffusion in solids, mechanical properties, strengthening and failure mechanisms, phase diagrams and transformations, corrosion and degradation of materials, metal alloys, ceramics, polymers, composites, as well as their electrical, thermal, magnetic, and optical properties. Quantitative analyses will be emphasized. (3-0) R

MSEN 5310 Thermodynamics of Materials (3 semester credit hours) 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. (3-0) S

MSEN 5320 Materials Science for Sustainable Energy (3 semester credit hours) Sustainable energy solutions require examining current fossil fuel supply, climate change, and renewable energy source development. Fossil fuel supply and climate change are intimately related, and the global community is actively developing renewable energy source to replace the fossil fuel and minimize its impact on the climate change. Materials science will enable diverse renewable energy technologies (solar cell, biofuel, wind, geothermal etc.) and their practical utilization (energy storage, fuel cell, electrical vehicles, etc.). This course will examine energy and climate issues and sustainable energy solutions with emphasis on the role of materials science. (3-0) T

MSEN 5331 (CHEM 5331) Advanced Organic Chemistry I (3 semester credit hours) Modern concepts of bonding and structure in covalent compounds. Static and dynamic stereochemistry and methods for study. Relationships between structure and reactivity. Prerequisite: Undergraduate organic chemistry or instructor consent required. (3-0) Y

MSEN 5333 (CHEM 5333) Advanced Organic Chemistry II (3 semester credit hours) Application of the principles introduced in CHEM 5331, emphasizing their use in correlating the large body of synthetic/preparative organic chemistry. Prerequisite: CHEM 5331 or MSEN 5331. (3-0) R

MSEN 5340 (BMEN 6360 and CHEM 5340) Advanced Polymer Science and Engineering (3 semester credit hours) Polymer structure-property relations, Glass transition temperature and mechanical properties of polymers, Thermoplastics, thermostets, and elastomers, morphology of polymers, rheology of polymers, biodegradable and biocompatible polymers for drug delivery and tissue engineering applications. (3-0) R

MSEN 5341 (CHEM 5341) Advanced Inorganic Chemistry I (3 semester credit hours) Physical inorganic chemistry addressing topics in structure and bonding, symmetry, acids and bases, coordination chemistry and spectroscopy. Prerequisite: Undergraduate inorganic chemistry or instructor consent required. (3-0) Y

MSEN 5344 Thermal Analysis (3 semester credit hours) Differential scanning calorimetry; thermogravimetric analysis; dynamic mechanical and thermomechanical analysis; glass transition; melting transitions, relaxations in the glassy state, liquid crystalline phase changes. Prerequisite: MSEN 5360 or equivalent. (3-0) R

MSEN 5353 Integrated Circuit Packaging (3 semester credit 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 will be presented. General review of analytical techniques used in the evaluation and failure analysis of microelectronic packages. Prerequisite: **MSEN 6324**. (3-0) R

**MSEN 5355 (CHEM 5355)** Analytical Techniques I (3 semester credit hours) Study of fundamental analytical techniques, including optical spectroscopic techniques, mass spectrometry, and microscopic and surface analysis methods. (3-0) Y

**MSEN 5356 (CHEM 5356)** Analytical Techniques II (3 semester credit hours) Study of chromatography (GC, LC, CZE), statistical methods (standard tests and ANOVA), chemical problem solving, and modern bio/analytical techniques such as biochips, microfluidics, and MALDI-MS. Prerequisite: **CHEM 5355** or instructor consent required. (3-0) R

**MSEN 5360** Materials Characterization (3 semester credit 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: **MSEN 5300**. Prerequisite or Corequisite: **MSEN 6319** or equivalent. (3-0) S

**MSEN 5361 (CHEM 5361)** Fundamentals of Surface and Thin Film Analysis (3 semester credit hours) Survey of materials characterization techniques; Rutherford backscattering; secondary ion mass spectroscopy; ion channeling; scanning tunneling and transmission microscopy; x-ray photoelectron and Auger electron spectroscopy; x-ray and electron diffraction. Prerequisite: **MSEN 5360** or equivalent. (3-0) R

**MSEN 5370** Ceramics and Metals (3 semester credit hours) Emphasis on structure-property relationships: chemical bonding, crystal structures, crystal chemistry, electrical properties, thermal behavior, defect chemistry. Chemical and physical properties of metals and alloys. Topics include: powder preparation, sol-gel synthesis, densification, toughening mechanisms, crystal structure, thermodynamics, phase diagrams, phase transformations, oxidation, mechanical, electrical and magnetic properties. Prerequisites: **MSEN 5300** and **MSEN 5310** or equivalent. (3-0) R

**MSEN 5371 (PHYS 5371)** Solid State Physics (3 semester credit hours) Symmetry description of crystals, bonding, properties of metals, electronic band theory, thermal properties, lattice vibration, elementary properties of semiconductors. Prerequisites: **PHYS 5301** and **PHYS 5320** or equivalent. (3-0) Y

**MSEN 5375** Electronic Devices Based On Organic Solids (3 semester credit hours) Solid state device physics based on organic condensed matter structures, including: OLEDs (organic light emitting diodes), organic FETs, organic lasers, plastic photocells, molecular electronic chips. (3-0) R

**MSEN 5377 (PHYS 5377)** Computational Physics of Nanomaterials (3 semester credit hours) This course introduces atomistic and quantum simulation methods and their applications to modeling study nanomaterials (nanoparticles, nanowires, and thin films). The course has three main parts: basic theory of materials (thermodynamics, statistical mechanics, and solid state physics), computational methods to model materials systems, and applications to practical problems. There are three main themes of the course: structure-property relationship of nanomaterials; atomistic modeling for atomic structure optimization; and quantum simulations for electronic structure study and functional property analysis. Prerequisite: **MSEN 6319** or equivalent. (3-0) R

**MSEN 5383 (EEMF 5383 and PHYS 5383)** Plasma Technology (3 semester credit hours) Hardware oriented study of useful laboratory plasmas. Topics will include vacuum technology, gas kinetic theory, basic plasma theory and an introduction to the uses of plasmas in various industries. (3-0) T

**MSEN 5410 (BIOL 5410)** Biochemistry (4 semester credit hours) Emphasis is on metabolic biochemistry, especially as it relates to human disease states. Prerequisite: at least one
semester of undergraduate biochemistry and instructor consent required. (4-0) Y

**MSEN 5440 (BIOL 5440)** Cell Biology (4 semester credit hours) Molecular architecture and function of cells and subcellular organelles; structure and function of membranes; hormone and neurotransmitter action; growth regulation and oncogenes; immune response; eukaryotic gene expression. Prerequisite: BIOL 5420 or equivalent or instructor consent required. (4-0) Y

**MSEN 6310 (MECH 6367)** Mechanical Properties of Materials (3 semester credit hours) Phenomenology of mechanical behavior of materials at the macroscopic level and the relationship of mechanical behavior to material structure and mechanisms of deformation and failure. Topics covered include elasticity, viscoelasticity, plasticity, creep, fracture, and fatigue. Prerequisite: MECH 2320 or MSEN 5300 or equivalent. (3-0) R

**MSEN 6313 (EEOP 6313)** Semiconductor Opto-Electronic Devices (3 semester credit hours) Physical principles of semiconductor optoelectronic devices: optical properties of semiconductors, optical gain and absorption, wave guiding, laser oscillation in semiconductors, LEDs, physics of detectors, applications. Prerequisite: EE 3310 or equivalent. (3-0) R

**MSEN 6319** Quantum Mechanics for Materials Scientists (3 semester credit hours) Quantum-mechanical foundation for study of nanometer-scale materials. Principles of quantum physics, operators and Dirac notation, stationary-states for one-dimensional potentials, and the hydrogen atom. Introduction to: angular momentum and spin, chemical bonding and molecular orbital theory, and crystalline solids and band theory. (3-0) Y

**MSEN 6320 (EEMF 6320)** Fundamentals of Semiconductor Devices (3 semester credit hours) Semiconductor material properties, band structure, equilibrium carrier distributions, non-equilibrium current-transport processes, and recombination-generation processes. Corequisite: EEMF 6319 or equivalent. (3-0) Y

**MSEN 6321 (EEMF 6321)** Active Semiconductor Devices (3 semester credit hours) The physics of operation of active devices will be examined, including p-n junctions, bipolar junction transistors and field-effect transistors: MOSFETs, JFETS, and MESFETS. Active two-terminal devices and optoelectronic devices will be presented. Recommended corequisite: EEMF 6320 or MSEN 6320. (3-0) Y

**MSEN 6322 (EEMF 6322 and MECH 6348)** Semiconductor Processing Technology (3 semester credit hours) Modern techniques for the manufacture of semiconductor devices and circuits. Techniques for both silicon and compound semiconductor processing are studied as well as an introduction to the design of experiments. Topics include: wafer growth, oxidation, diffusion, ion implantation, lithography, etch and deposition. (3-0) T

**MSEN 6323** Quantum Mechanics for Materials Scientists II (3 semester credit hours) Perturbation theory and approximation methods; scattering theory; elements of second quantization and many-body theory; exchange and spin statistics; interaction of radiation with matter; relativistic effects; band structure, and vibrational and optical properties of crystals; optionally, quantum information theory. Prerequisite: MSEN 6319 (or equivalent with permission of instructor.) (3-0) Y

**MSEN 6324 (EEMF 6324)** Electronic, Optical and Magnetic Materials (3 semester credit hours) Foundations of materials properties for electronic, optical and magnetic applications. Electrical and thermal conduction, elementary quantum physics, modern theory of solids, semiconductors and devices, dielectrics, magnetic and optical materials properties. Prerequisite: MSEN 5300 or equivalent. (3-0) T

**MSEN 6325** Semiconductor Materials, Defects, and Devices (3 semester credit hours) This course provides the fundamental basis for understanding semiconductor electronic materials and devices. Starting from basic materials properties and electronic band structure, intrinsic and extrinsic semiconductors, the necessary derivation of carrier distributions, transport processes and equations, ac and dc response in junctions and capacitors, and the impact of bulk and interface defects are explored in traditional and novel nanoelectronic devices.
Prerequisites: MSEN 5310 and MSEN 6319 and MSEN 6324. (3-0) Y
MSEN 6327 (EEMF 6327) Semiconductor Device Characterization (3 semester credit hours) This course will describe the theoretical and practical considerations associated with the most common electrical and reliability characterization techniques used in the semiconductor industry. Prerequisite: (EEMF 6320 or MSEN 6320 or MSEN 6325 or equivalent) or instructor consent required. (3-0) T
MSEN 6330 Phase Transformations (3 semester credit hours) Thermodynamic, 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: MSEN 5310 or equivalent. (3-0) R
MSEN 6338 Advanced Theory of Semiconductors: Electronic Structure and Transport (3 semester credit hours) This course discusses: 1. The electronic structure of semiconductors and small semiconductor structures starting from basic condensed-matter theory; 2. The nature of elementary excitations (such as phonons, plasmons, interface and surface excitations, etc.) in terms of the many-body, second quantization language; 3. The interaction of electrons with these excitations, as well as photons; and, 4. The equations which govern electronic transport at the nanometer scale. Recommended prior coursework: one or more semesters of graduate quantum mechanics or equivalent. (3-0) T
MSEN 6339 Nanostructured Materials: Synthesis, Properties and Application (3 semester credit hours) Exploration of the synthesis, properties and applications of quantum dots, wells, rods, wires, particles and related nanostructures. The theoretical and experimental evidence for quantum-confinement effects, which are of considerable fundamental and applied interest, will be discussed. The manipulation of surface properties of nanostructures, their incorporation into bulk nanocomposites and their application to technological devices will be discussed. Prerequisites or Corequisites: MSEN 5310 and MSEN 5360 and MSEN 6319 and MSEN 6324, or equivalent. (3-0) T
MSEN 6340 Introduction to Electron Microscopy (3 semester credit hours) Theory and applications of scanning and transmission electron microscopy; sample preparation, ion beam and electron beam imaging techniques. Prerequisite: MSEN 5360 or equivalent. (2-1) Y
MSEN 6341 Advanced Electron Microscopy (3 semester credit hours) Theory and applications of advanced transmission electron microscopy; energy dispersive x-ray spectroscopy, electron energy loss spectroscopy and special techniques. Prerequisite: MSEN 6340. (2-1) Y
MSEN 6348 (EEMF 6348 and MECH 6341) Lithography and Nanofabrication (3 semester credit hours) Study of the principles, practical considerations, and instrumentation of major lithography technologies for nanofabrication of devices and materials. Advanced photolithography, electron beam lithography, nanoimprint lithography, x-ray lithography, ion beam lithography, soft lithography, and scanning probe lithography, basic resist and polymer science, applications in nanoelectronic and biomaterials. (3-0) Y
MSEN 6350 Imperfections in Solids (3 semester credit hours) Point defects in semiconductors, metals, ceramics, and nonideal defect structures; nonequilibrium conditions produced by irradiation or quenching; effects of defects on electrical and physical properties, effects of defects at interfaces between differing materials. Prerequisites: MSEN 5310 and MSEN 6324, or equivalent. (3-0) R
MSEN 6355 (BMEN 6355) Nanotechnology and Sensors (3 semester credit hours) Introduction to the concept of nanotechnology, in context toward designing sensors/diagnostic devices. Identifying the impact of nanotechnology in designing "state-of-the-art" sensors for healthcare applications. Topics include: nanotechnology and nanomaterials, principles of sensing and transduction and heterogeneous integration toward sensor design. (3-0) Y
MSEN 6358 (BIOL 6358) Bionanotechnology (3 semester credit hours) Protein, nucleic acid and
laid structures. Macromolecules as structural and functional units of the intact cell. Parallels between biology and nanotechnology. Applications of nanotechnology to biological systems.

(3-0) T

**MSEN 6361** Deformation Mechanisms in Solid Materials (3 semester credit hours) Linear elastic fracture mechanics, elastic-plastic fracture mechanics, time dependent failure, creep and fatigue, experimental analysis of fracture, fracture and failure of metals, ceramics, polymers and composites. Failure analysis related to material, product design, manufacturing and product application. Prerequisite: **MSEN 5300** or **MECH 6301** or **MSEN 6310** or equivalent. (3-0) T

**MSEN 6362** Diffraction Science (3 semester credit hours) Diffraction theory; scattering and diffraction experiments; kinematic theory; dynamical theory; x-ray topography; crystal structure analysis; disordered crystals; quasi-crystals. (3-0) R

**MSEN 6371** (**PHYS 6371**) Advanced Solid State Physics (3 semester credit hours) Continuation of **MSEN 5371** or **PHYS 5371**, transport properties of semiconductors, ferroelectricity and structural phase transitions, magnetism, superconductivity, quantum devices, surfaces. Prerequisite: **MSEN 5371** or **PHYS 5371** or equivalent. (3-0) R

**MSEN 6374** (**PHYS 6374**) Optical Properties of Solids (3 semester credit hours) Optical response in solids and its applications. Lorentz, Drude and quantum mechanical models for dielectric response function. Kramers-Kronig transformation and sum rules considered. Basic properties related to band structure effects, excitons and other excitations. Experimental techniques including reflectance, absorption, modulated reflectance, Raman scattering. Prerequisite: **MSEN 5371** or **PHYS 5371** or equivalent. (3-0) R


**MSEN 6380** (**MECH 6357**) Phase Transformations and Kinetic processes in Materials (3 semester credit hours) This course covers diffusion, interfacial motion, nucleation, precipitation, order-disorder transitions, phase transformations, and dynamical processes at grain boundaries and on surfaces. Both macroscopic and atomic-scale approaches are used to understand these phenomena. Particular applications considered include phase transformations in bulk materials, surface evolution and thin-film growth, semiconductor processing, and nanomaterials synthesis. Prerequisites: (**MSEN 5300** and **MSEN 5310**) or equivalents. (3-0) T

**MSEN 6381** (**MECH 6358**) Advanced Ceramic Materials (3 semester credit hours) This course covers fundamental material properties and modern applications of ceramic materials. The mechanical, optical, electronic and chemical properties of advanced ceramic materials are related to atomic structures and defects. Both conventional engineering ceramics and emerging applications of ceramics in nanotechnology, medical devices, and clean energy are reviewed. Advanced experimental and theoretical approaches in ceramics research are also discussed. Prerequisites: (**MSEN 5300** and **MSEN 5310**) or equivalents. (3-0) T

**MSEN 6382** (**EEMF 6382** and **MECH 6347**) Introduction to MEMS (3 semester credit hours) Study of micro-electro-mechanical devices and systems and their applications. Microfabrication techniques and other emerging fabrication processes for MEMS are studied along with their process physics. Principles of operations of various MEMS devices such as mechanical, optical, thermal, magnetic, chemical/biological sensors/actuators are studied. Topics include: bulk/
surface micromachining, LIGA, microsensors and microactuators in multiphysics domain. (3-0) 

**MSEN 6383 (MECH 6359)** Modern Physical Metallurgy (3 semester credit hours) This course provides a basic understanding of the underlying principles that determine microstructural evolution in bulk materials and thin films during processing, and how microstructure determines their properties and performance in service. The course covers fundamental crystallography, including atomistic crystal structures and defect structures; thermodynamics and phase diagrams; kinetics of phase transformations; alloy and micro-structural engineering; and structure-property relationships that determine mechanical and electrical performance. Additionally, metallization and the reliability of multilevel interconnection and packaging for semiconductor and electronic devices are discussed. Prerequisites: (MECH 5300 and MSEN 5310) or equivalents. (3-0) 

**MSEN 6V98** Thesis (3-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([3-9]-0) 

**MSEN 7320 (EEMF 7320)** Advanced Semiconductor Device Theory (3 semester credit hours) Quantum mechanical description of fundamental semiconductor devices; carrier transport on the submicron scale; heterostructure devices; quantum-effect devices. Prerequisites: EEMF 6320 and EEMF 6321. (3-0) 

**MSEN 7V80** Special Topics in Materials Science and Engineering (1-6 semester credit hours) May be repeated for credit as topics vary (9 semester credit hours maximum). ([1-6]-0) 

**MSEN 8V40** Individual Instruction in Materials Science and Engineering (1-6 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([1-6]-0) 

**MSEN 8V70** Research in Materials Science and Engineering (3-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([3-9]-0) 

**MSEN 8V99** Dissertation (1-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([1-9]-0)