Materials Science and Engineering

Graduate Study

The department offers work toward the following advanced degrees: Master of Engineering in Materials Science and Engineering, Master of Science in Materials Science and Engineering and Doctor of Philosophy in Materials Science and Engineering.

Built on a foundation of thermodynamics, kinetics of phase transformations, mechanical behavior, physical properties, solid state science, and the structure and chemistry of materials, the graduate program offers advanced studies in many areas of materials science and engineering, including the design and control of materials for structural, electronic, photonic, magnetic, optical, and biological functionality. Graduates of the program have a fundamental understanding of the critical aspects of the field and how they are applied to real materials systems. The program is highly flexible and research-oriented, where students work carefully with their major professor in tailoring the various academic and research components to meet their interests.

With the ability to address complex problems in materials science while considering the various constraints inherent to both academic and industrial environments, our graduates are well prepared for a wide range of academic and research-related careers. They are skilled in carrying out independent and collaborative research, able to communicate effectively in formal and informal settings, and are proficient at writing persuasive technical articles and grant proposals.

The department boasts excellent facilities for academic materials research, maintaining a wide range of faculty laboratories across the ISU campus. In addition, departmental research is highly integrated with the operation of several Research Centers, such as the Ames Laboratory, the Center for Nondestructive Evaluation, the Microelectronics Research Center, and the Center for Advanced Technology Development. These laboratories offer excellent resources and opportunities for graduate student research.

Prerequisite to major graduate work is completion of an undergraduate curriculum in physical science, biological science, or engineering discipline. Graduate students from disciplines other than materials science and engineering may expect that supplemental coursework will be needed, in addition to the required graduate coursework. Well qualified students (juniors) enrolled in the undergraduate materials engineering program at Iowa State University can apply to the Graduate College for admission to the concurrent enrollment program, where students may simultaneously pursue both master of science and bachelor of science degrees.

The requirements for the M. Eng., M.S. and Ph.D. degrees are established by the student's program of study committee within the established guidelines of the Graduate College. Minimum requirements include coursework, research (M.S. and Ph.D. only), proposal (M.S. and Ph.D. only), preliminary oral examination (Ph.D. only), dissertation (M.S. and Ph.D. only), and a final oral examination (M.S. and Ph.D. only). Academic coursework requirements include 31 credits for the M.Eng. degree, 21 credits for the M.S. degree and 32 credits for the Ph.D., with additional specific rules for choices available from the department.

There are no foreign language requirements for any of the graduate degrees administered by the Department of Materials Science and Engineering. Graduate students wishing to declare a formal minor in materials science and engineering will have at least one materials science and engineering faculty member serving on their program of study committee. For the M. Eng., M.S. and Ph.D. degrees, they will take a minimum of 8 materials science and engineering course credits for the M. Engr. or M.S. degrees and a minimum of 12 materials science and engineering course credits for the Ph.D. degree.

Courses primarily for graduate students, open to qualified undergraduates:

M S E 510. Fundamentals of Structure and Chemistry of Materials.
(3-0) Cr. 3. F. *Prereq: MATH 165, PHYS 221, and CHEM 167*
Geometric and algebraic representations of symmetry. Pair distribution function. Structure, chemistry, and basic properties of covalent, ionic, and metallic solids, glasses and liquids, and polymers. Interactions of materials with particles and waves. Relationships between direct and reciprocal spaces. The kinematical theory of diffraction, with an introduction to the dynamical theory.

M S E 519. Magnetism and Magnetic Materials.
(Cross-listed with E E). (3-0) Cr. 3. F. *Prereq: E E 311, MAT E 211 or E E 271 or E E 272 or PHYS 364*
Magnetic fields, flux density and magnetization. Magnetic materials, magnetic measurements. Magnetic properties of materials. Domains, domain walls, domain processes, magnetization curves and hysteresis. Types of magnetic order, magnetic phases and critical phenomena. Magnetic moments of electrons, theory of electron magnetism. Technological application, soft magnetic materials for electromagnets, hard magnetic materials, permanent magnets, magnetic recording technology, magnetic measurements of properties for materials evaluation.

M S E 520. Thermodynamics and Kinetics in Multicomponent Materials.
(3-0) Cr. 3. F. *Prereq: MAT E 311 or CHEM 321, MATH 266 or MATH 267*
A review of the fundamental principles of heat, work, basic thermodynamic relations, and criteria for equilibrium. Analytical treatments for the thermodynamic description of multicomponent chemical solutions and reacting systems are developed and employed to predict phase equilibria in materials systems. Builds on the thermodynamic construction to treat the kinetics of chemical reactions and phase transformations. Topics include general first order and second order transitions, along with chemical diffusion. Detailed examples involving nucleation and diffusion limited growth, spinodal decomposition, martensitic transformations, magnetic and electric transitions, and glass formation will be considered.

M S E 521. Mechanical Behavior and Manufacturing of Polymers and Composites.
(Cross-listed with M E). (3-0) Cr. 3. Alt. S., offered 2013. *Prereq: M E 324 or MAT E 272 and E M 324*
Effect of chemical structure and morphology on properties. Linear viscoelasticity, damping and stress relaxation phenomena. Structure and mechanics of filler and fiber reinforced composites. Mechanical properties and failure mechanisms. Material selection and designing with polymers. Processing of polymer and composite parts.

M S E 530. Solid State Science.
(3-0) Cr. 3. S. *Prereq: MAT E 334 or E E 332 or PHYS 322*
Development of a quantitative description of the electronic structure of solids starting with fundamentals of atoms, atomic bonding, basic crystallography, and band theory of solids. Continuum properties of solids in response to electromagnetic fields and thermal gradients. Quantitative description of the atomistic properties of solids through electron-electron interactions, electron-phonon interactions, and dipole interactions.

M S E 539. Electronic Properties of Materials.
(Cross-listed with E E). (3-0) Cr. 3. *Prereq: E E 332 or MAT E 331 or PHYS 322*
Review of classical and quantum mechanical descriptions of electrons in solids, band theory, metallic conduction, lattice vibrations, semiconductors, semiconductor devices, dielectrics, polarization, dielectric relaxation, crystal anisotropy, ferroelectricity, piezoelectricity, superconductivity, magnetism, device applications.

M S E 540. Mechanical Behavior of Materials.
(3-0) Cr. 3. F. *Prereq: MAT E 418, MATH 266 or MATH 267*
Mechanical behavior of materials with emphasis on micromechanics of deformation in three generic regimes: elasticity, plasticity, and fracture. A materials science approach is followed to understand and model the mechanical behavior that combines continuum mechanics, thermodynamics, kinetics, and microstructure. Some topics include elastic properties of materials, permanent deformation mechanisms at different temperatures (e.g., via dislocation motion and creep), and fracture in ductile and brittle materials. Specific classes of materials that are studied: metals, ceramics, polymers, glasses and composites.

M S E 550. Fundamentals of Nondestructive Evaluation.
(Cross-listed with E M). (3-2) Cr. 4. S. *Prereq: E M 324, MATH 385*
Principles of five basic NDE methods and their application in engineering inspections. Materials behavior and simple failure analysis. NDE reliability, and damage-tolerant design. Advanced methods such as acoustic microscopy, laser ultrasonics, thermal waves, computed tomography, and thermoelectrics are analyzed. Laboratory experiments on all basic methods: ultrasonics, eddy currents, x-ray, liquid penetrants, magnetic testing, and visual inspection are performed.

M S E 551. Characterization Methods in Materials Science.
(2-3) Cr. 3. Alt. S., offered 2015. *Prereq: MAT E 214*
Characterization of ceramic, metal, polymer and glassy materials using modern analytical techniques. Spectroscopic (IR, Raman, UV/VIS/NIR, and NMR), thermal (DSC, DTA/TGA, and DMA) methods, mechanical and rheological testing, magnetic and electrical characterization, and powder characterization.

M S E 552. Scanning and Auger Electron Microscopy.
(2-3) Cr. 3. F. *Prereq: PHYS 222*
Characterization of materials using scanning electron microscope (SEM), electron microprobe, and auger spectrometer. Compositional determination using energy and wavelength dispersive x-ray and Auger spectroscopies. Specimen preparation. Laboratory covers SEM operation.

M S E 554. Polymer Composites and Processing.
(Dual-listed with M S E 454). (3-0) Cr. 3. S. *Prereq: MAT E 351*
Basic concepts in polymer composites, blends, and block copolymers. Phase separation and miscibility, microstructures and mechanical behavior. Fiber reinforced and laminated composites. Viscosity, rheology, viscoelasticity of polymers. Polymer melt processing methods such as injection molding and extrusion; selection of suitable processing methods and their applications.

M S E 556. Biomaterials.
(Dual-listed with M S E M S E 456). (3-0) Cr. 3. F. *Prereq: MAT E 216 or MAT E 273 or MAT E 392*
Presentation of the basic chemical and physical properties of biomaterials, including metals, ceramics, and polymers, as they are related to their manipulation by the engineer for incorporation into living systems. Role of microstructure properties in the choice of biomaterials and design of artificial organs, implants, and prostheses.

M S E 557. Chemical and Physical Metallurgy of Rare Earth Metals.
(Dual-listed with M S E 457). (3-0) Cr. 3. Alt. S., offered 2014. *Prereq: MAT E 311 or CHEM 325 AND CHEM 324 or PHYS 322*
Electronic configuration, valence states, minerals, ores, beneficiation, extraction, separation, metal preparation and purification. Crystal structures, phase transformations and polymorphism, and thermochemical properties of rare earth metals. Chemical properties: inorganic and organometallic compounds, alloy chemistry, nature of the chemical bonding. Physical properties: mechanical and elastic properties, magnetic properties, resistivity, and superconductivity. Nonmajor graduate credit.

M S E 564. Fracture and Fatigue.
(Cross-listed with E M, M E, AER E). (3-0) Cr. 3. Alt. F., offered 2012. *Prereq: E M 324 and either MAT E 216 or MAT E 273 or MAT E 392. Undergraduates: Permission of instructor*
Materials and mechanics approach to fracture and fatigue. Fracture mechanics, brittle and ductile fracture, fracture and fatigue characteristics, fracture of thin films and layered structures. Fracture and fatigue tests, mechanics and materials designed to avoid fracture or fatigue.

M S E 569. Mechanics of Composite and Combined Materials.
(Cross-listed with E M, AER E). (3-0) Cr. 3. Alt. S., offered 2012. *Prereq: E M 324*
Mechanics of fiber-reinforced materials. Micromechanics of lamina. Macromechanical behavior of lamina and laminates. Strength and interlaminar stresses of laminates. Failure criteria. Stress analysis of laminates. Thermal moisture and residual stresses. Joints in composites.

M S E 570. Toying With Technology for Practicing Teachers.
(Cross-listed with C I). (2-0) Cr. 2. SS. *Prereq: C I 201 or 202 or 505 or equivalent*
A project-based, hands-on learning course. Technology literacy, appreciation for technological innovations, principles behind many technological innovations, hands-on experiences based upon simple systems constructed out of LEGOs and controlled by small microcomputers. Other technological advances with K-12 applications will be explored. K-12 teachers will leave the course with complete lesson plans for use in their classrooms.

M S E 588. Eddy Current Nondestructive Evaluation.
(Dual-listed with M S E 488). (Cross-listed with E E). (3-0) Cr. 3. Alt. F., offered 2011. *Prereq: MATH 265 and (MAT E 216 or MAT E 272 or E E 311 or PHYS 364)*
Electromagnetic fields of various eddy current probes. Probe field interaction with conductors, cracks and other material defects. Ferromagnetic materials. Layered conductors. Elementary inversion of probe signals to characterize defects. Special techniques including remote-field, transient, potential drop nondestructive evaluation and the use of Hall sensors. Practical assignments using a 'virtual' eddy current instrument will demonstrate key concepts.

M S E 590. Special Topics.
Cr. arr. Repeatable. *Prereq: Permission of instructor*

M S E 599. Creative Component.
Cr. arr. Repeatable.

Courses for graduate students:

M S E 601. Materials Seminar.
(1-0) Cr. 1. Repeatable. F.S. *Prereq: MSE Graduate Student Status*
Seminar course - presentations given on a weekly basis by leading U.S. and International researchers that are experts in their respective fields closely related to Materials Science.

M S E 610. Academic Teaching Practices.
(2-0) Cr. 2. Repeatable. F.S. *Prereq: Permission of instructor*
Provides instruction and directed experience in undergraduate level teaching practices. Students engage in lesson planning, classroom/laboratory teaching, student and course assessment, web-based lessons, and other aspects of academic course delivery.

M S E 620. Fundamentals of Phase Transformations.
(3-0) Cr. 3. Alt. S., offered 2012. *Prereq: M S E 520*
Explores various advanced theoretical treatments of the energetics and kinetics of multicomponent materials. Topics include analytical and computational descriptions of thermodynamic quantities, experimental measurement of essential physical properties, analytical and computational treatments of kinetic processes, and the use of theoretical predictions of phase equilibria and evolution in materials systems.

M S E 630. Physical Properties of Solids.
(3-0) Cr. 3. Alt. F., offered 2012. *Prereq: M S E 530*
Advanced course in the behavior of solids within the framework of solid state physics and chemistry. Includes magnetic, dielectric, transport, and optical phenomena in solids. Influence of phase transformations and crystal symmetry on the physical properties.

M S E 651. Powder Diffraction Methods.
(3-0) Cr. 3. Alt. S., offered 2013. *Prereq: M S E 510*
Advanced structural characterization of materials using powder diffraction. Production of X-ray and neutron radiation. Review of symmetry, group and kinematical theories of diffraction. Mathematical and computational backgrounds of powder diffraction data. Introduction to single crystal diffraction methods, origin of powder diffraction pattern, history of the technique. Modern powder diffraction methods. Indexing of powder diffraction patterns, figures of merit, precise lattice parameters. Phase problem, determining crystal structures from symmetry and geometry, Patterson, direct and Fourier methods. Rietveled method, precise crystal structures: atomic parameters, qualitative and quantitative phase identification, preferred orientation, grain size, strain, residual stress, order-disorder. Powder diffraction at non-ambient conditions. Applications of powder diffraction: data bases, phase transformations, phase diagrams, local structures, magnetism.

M S E 690. Advanced Topics in Materials Science.
Cr. arr. Repeatable. *Prereq: Permission of instructor*

M S E 697. Engineering Internship.
Cr. R. Repeatable. F.S.SS. *Prereq: Permission of department, graduate classification*
One semester and one summer maximum per academic year professional work period. Offered on a satisfactory-fail basis only.

M S E 699. Research.
Cr. arr. Repeatable.

M S E M S E 456. Biomaterials.
(Dual-listed with M S E 556). (3-0) Cr. 3. F. *Prereq: MAT E 216 or MAT E 273 or MAT E 392*
Presentation of the basic chemical and physical properties of biomaterials, including metals, ceramics, and polymers, as they are related to their manipulation by the engineer for incorporation into living systems. Role of microstructure properties in the choice of biomaterials and design of artificial organs, implants, and prostheses.