MATERIALS SCIENCE AND ENGINEERING

The materials science and engineering department offers a variety of educational and research opportunities for graduate study including degree programs in materials science and engineering, ceramic engineering, and metallurgical engineering. The department offers the following degrees: M.S. and Ph.D. in materials science and engineering, M.S. and Ph.D. in ceramic engineering, and M.S. and Ph.D. in metallurgical engineering. Further information regarding these degree programs may be found below and under the individual degree programs within this catalog.

The requirement for entry into one of these programs includes a baccalaureate degree in materials science or engineering, ceramic engineering or science, glass science or technology, or metallurgical science or engineering. A baccalaureate degree in physics, chemistry, chemical engineering, or related discipline may also be acceptable.

In the areas of glass, ceramic, and biomaterials, the department carries out research in electronic ceramics, high temperature materials, structural ceramics, composites, ceramic processing, laser glasses, and nuclear waste encapsulation glasses. Fundamental and applied interests include structure and its relation to the properties of ceramics and glasses; defect chemistry, thermochemistry and phase equilibria; electrical, dielectric, optical, thermal and mechanical properties of ceramics; ceramic-ceramic, ceramic-metal, and ceramic-polymer composites; compositional effects on the optical properties and chemical corrosion of glass; solid oxide fuel cells; high temperature superconducting ceramics; ferroelectric ceramics; glasses and ceramics for biomedical applications such as drug delivery and medical implants; and processing, forming, and microstructure control of structural and functional ceramics. The department has extensive facilities for the synthesis, forming, and fabrication of ceramics and glasses, as well as for the detailed characterization of the properties of ceramics. A mechanical testing laboratory is available for characterizing mechanical properties under controlled temperature and atmospheric conditions.

In the areas of metallurgical science and engineering, the department carries out research in physical and mechanical metallurgy, extractive metallurgy, metals casting, joining and forming, and manufacturing metallurgy. Principal research interests include steel manufacturing and processing, additive manufacturing of advanced metallic materials, electro-metallurgical processes, computation methods for materials synthesis and processing, radiation effects on materials, environmental aspects of metal manufacturing, and treatment of metals industry wastes. Capabilities for research in these areas include: (1) a department foundry with facilities for green sand casting, centrifugal casting, lost foam casting, and permanent mold casting, and metal joining, (2) controlled hot rolling and quenching, (3) multiple advanced additive manufacturing systems, (4) physical testing of metals under controlled temperature and atmospheric conditions, and (5) pilot scale electrowinning, electrorefining and solvent extraction facilities.

In the area of biomaterials the department carries out research in the synthesis and characterization of novel biomaterials, the design and fabrication of scaffolds for tissue engineering of biological tissues, interactions of biomaterials with living systems, and tissue-engineered restoration of biological tissues.

The department also has a strong affiliation with the Materials Research Center (MRC) at Missouri S&T, which houses major instrumentation for materials characterization. Faculty members within the MSE department are either senior research investigators or research investigators in this nationally recognized center. Facilities available within the MRC to support graduate research include electron microscopy, thermal analysis, Auger Electron Spectroscopy, FIB (Focused Ion Beam) x-ray diffraction, together with grazing incidence for film analysis, among others. Extensive capabilities for materials coatings, preparation and analysis are also available.

Degree Requirements

M.S. and Ph.D. degrees are offered in materials science and engineering. Students may apply for either degree and may be admitted directly to the Ph.D. program upon approval (i.e., there is no M.S. requirement). Depending upon their intended career path, students may be encouraged to pursue one of the MSE graduate degrees or other degree programs noted above.

The total number of hours required for the M.S. in materials science and engineering is 30. The M.S. with thesis is oriented toward the completion of a research project and the degree requirements are 18 hours of course work and 12 hours of research. It is recommended that the student complete the core courses offered by the department including MS&E 6110, MS&E 6120, and MS&E 6130 which are graduate level crystallography, thermodynamics and kinetics. At least 6 hours of course work must be 6000-level courses. It is recommended that six additional hours be completed outside of the department. The other courses are chosen with the approval of the advisor.

For the non-thesis M.S. degree in materials science and engineering, 30 hours of course work must be completed with a minimum of 12 hours at the 6000-level.

The total number of hours required for the Ph.D. degree in materials science and engineering is 72. Ph.D. students are required to complete the three core courses, MS&E 6110, MS&E 6120, and MS&E 6130. To advance to Ph.D. candidacy, the student must take and pass a qualifying exam. This must be completed prior to the beginning of the fifth semester after entering the graduate program. Students must also take and pass the comprehensive exam in accordance with Missouri S&T rules.

Advanced Engineering Materials

Missouri University of Science and Technology offers a graduate certificate in Advanced Engineering Materials for working professionals. The graduate certificate program consists of four courses from existing graduate-level courses. While the students admitted to the certificate program will have non-matriculated status, if they complete the four course sequence with a grade of B or better in each of the courses taken, they will be admitted to the master's degree program, if they so choose. The certificate credits taken by students admitted to the master's program will count toward their master's degrees.

The Advanced Engineering Materials Certificate Program is open to all persons holding a B.S., M.S., or Ph.D. degree in Engineering, Science, and/or Mathematics and who have a minimum of one year of professional employment experience, or are currently accepted into a graduate degree program at Missouri S&T. Once admitted to the program, the student must take the four designated courses (provided in the curriculum section). In order to receive a Graduate Certificate, the student must have an average cumulative grade point of 3.0 or better in the certificate

courses. Once admitted to the program, a student will be given three years to complete the program.

Students admitted to the Advanced Engineering Materials Certificate Program will have non-degree graduate status, however, they will earn graduate credit for the courses they complete. If the four-course sequence is completed with a grade of B or better in each of the courses taken, the student, upon application, will be admitted to the Master's degree program sponsoring the graduate certificate, provided that all other program prerequisites and admission requirements are met. The certificate credits taken by the students admitted to the M.S. degree program will count towards their master's degrees. Students who do not have all of the prerequisite courses necessary to begin the courses in the Advanced Engineering Materials Certificate Program will be allowed to take "bridge" courses at either the graduate or undergraduate level to prepare for the formal certificate courses.

Students enrolled in this certificate will take one required course and three elective courses.

Required Course:		
MET ENG 5810	Principles Of Engineering Materials	3
Any three of the following courses:		
CER ENG 5230	Glass Science And Engineering	3
CER ENG 5310	Advanced Ceramic Processing	3
CER ENG 6230	Composite Materials	3
MS&E 5230	Energy Materials	3
MET ENG 5150	Introduction to Metal Additive Manufacturing	3
MET ENG 5330	Nonferrous Alloys	3

Materials for Extreme Environments

Missouri University of Science and Technology offers a graduate certificate Materials for Extreme Environments for working professionals. The graduate certificate program consists of four courses from existing graduate-level courses. While the students admitted to the certificate program will have non-matriculated status, if they complete the four course sequence with a grade of B or better in each of the courses taken, they will be admitted to the master's degree program, if they so choose. The certificate credits taken by students admitted to the master's program will count toward their master's degrees.

The Materials for Extreme Environments Certificate Program is open to all persons holding a B.S., M.S., or Ph.D. degree in Engineering, Science, and/or Mathematics and who have a minimum of one year of professional employment experience, or are currently accepted into a graduate degree program at Missouri S&T. Once admitted to the program, the student must take the four designated courses (provided in the curriculum section). In order to receive a Graduate Certificate, the student must have an average cumulative grade point of 3.0 or better in the certificate courses. Once admitted to the program, a student will be given three years to complete the program.

A student admitted to the Materials for Extreme Environments Certificate Program will have non-degree graduate status, however, they will earn graduate credit for the courses they complete. If the four-course sequence is completed with a grade of B or better in each of the courses taken, the student, upon application, will be admitted to the Master's degree program sponsoring the graduate certificate, provided that all other program prerequisites and admission requirements are met. The certificate credits taken by the students admitted to the M.S. degree program will count towards their master's degrees. Students who do not have all of the prerequisite courses necessary to begin the courses in the Materials for Extreme Environments Certificate Program will be allowed to take "bridge" courses at either the graduate or undergraduate level to prepare for the formal certificate courses.

Students enrolled in this certificate will take one required course and three elective courses.

Required Course:		
MET ENG 5810	Principles Of Engineering Materials	3
Any three of the following courses:		
CER ENG 5250	Refractories	3
CER ENG 6230	Composite Materials	3
MS&E 5220	Advanced Phase Equilibria	3
MET ENG 5170	Nuclear Materials I	3
MET ENG 5310	Corrosion and Its Prevention	3
MECH ENG 5212	Introduction to Finite Element Analysis	3

Laura Bartlett, Associate Professor
PHD Missouri Univeristy of Science and Technology
Melt processing and solidification phenomena, ferrous and non-ferrous casting, physical and mechanical metallurgy of irons and steels.

Richard K Brow, Curators Distinguished Professor
PHD Pennsylvania State University
Physics and chemistry of inorganic glasses; spectroscopic characterization of glass structure; biomaterials; optical materials.

Anthony Convertine, Roberta and G. Robert Couch Assistant Professor
PHD University of Southern Mississippi
Biomaterials, drug delivery, polymers, and sol-gel ceramics.

Fatih Dogan, Professor
PHD Technical University of Berlin
High temperature superconductors, solid oxide fuel cells, dielectrics, nanostructured electronic ceramics.

Arezoo Emdadi, Assistant Professor
PHD Missouri University of Science and Technology
Computational material science, applied mathematics, phase-field modeling, and fracture mechanics.

William G Fahrenholtz, Curators Distinguished Professor
PHD University of New Mexico
Thermodynamics, phase equilibria, reactive processing, ultra-high temperature ceramics.

Yijia Gu, Assistant Professor
PHD Pennsylvania State University
Additive manufacturing, computational material methods, and non-ferrous alloys.

Gregory E Hilmas, Curators Distinguished Professor and Department Chair
PHD University of Michigan-Ann Arbor
Microstructure-processing-mechanical property relationships in structural ceramics; novel processing techniques for the fabrication of ceramics and ceramic composites; biomaterials.

Wayne Huebner, Professor
PHD University of Missouri-Rolla
Structure-property relationships in ferroelectric, piezoelectric, and ionically-conducting materials.

Aditya Kumar, Associate Professor
PHD Ecole Polytechnique Federale de Lausanne (EPFL)
Composition-structure-property relationships in cementitious, silicate, and aluminosilicate materials.

David Lipke, Assistant Professor
PHD Georgia Institute of Technology
Composite materials, reaction processing, materials in extreme environments.

F Scott Miller, Teaching Professor
PHD University of Missouri-Rolla
Electron microscopy, materials characterization.

Michael Scott Moats, Professor
PHD University of Arizona
Extractive metallurgy, aqueous processing of metals, electrometallurgy.

Joseph W Newkirk, Professor and Department Chair of Nuclear Engineering and Radiation Science
PHD University of Virginia
Advanced additive manufacturing, intermetallic alloys, alloys for corrosion and high temperature, powder metallurgy.

Ronald J O'Malley, Professor
PHD Massachusetts Institute of Technology
F. Kenneth Iverson Chair Professor of Steelmaking Technologies.

Jeffrey D Smith, Professor
PHD University of Missouri-Rolla
Thermochemistry and high temperature phase equilibria of condensed and non-condensed ceramic systems; chemical, mineralogical and microstructural analysis of refractory materials.

David C Van Aken, Professor Emeritus[1]
PHD University of Illinois Urbana
Thermal spraying, fatigue and fracture, rapid solidification, advanced alloy design, electron microscopy.

Jeremy Lee Watts, Associate Research Professor
PHD Missouri S&T
Structure property relations, ultra-high temperature ceramics, thermomechanical properties, additive manufacturing.

Haiming Wen, Assistant Professor
PHD University of California-Davis
Bulk nanostructured metals, high-entropy alloys, advanced microstructural chracterization, nuclear materials.

Kelley Wilkerson, Assistant Teaching Professor
PHD Missouri University of Science and Technology
Refractory and high temperature research with additional interest in ceramic education and outreach.

MS&E 5000 Special Problems (IND 0.0-6.0)
Problems or readings on specific subjects or projects in the department. Consent of instructor required.

MS&E 5001 Special Topics (LEC 0.0-6.0)
This course is designed to give the department an opportunity to test a new course. Variable title.

MS&E 5010 Seminar (RSD 0.0-6.0)
(Variable) Discussion of current topics.

MS&E 5040 Oral Examination (IND 0.0)
(Variable) After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D students may be processed during intersession. Off-campus M.S. students must be enrolled in an oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

MS&E 5060 Chemistry of Construction Materials (LEC 3.0)
The objective of the course is to utilize fundamental concepts of materials science and chemistry to understand, analyze, and describe the chemistry of construction materials. Special focus is given to describe composition-reactivity-microstructure-property relations in various cementitious materials. Prerequisites: At least Senior standing.

MS&E 5099 Research (IND 0.0-15)
(Variable) Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

MS&E 5210 Tissue Engineering (LEC 3.0)
The course will use problem-based case studies to introduce junior and senior undergraduate students to the principles and clinical applications of tissue engineering. Topics include the use of biomaterials, scaffolds, cells, and external factors to develop implantable parts for the restoration, maintenance, or replacement of tissues and organs. Prerequisite: Junior or Senior standing. (Co-listed with Bio Sci 5240).

MS&E 5220 Advanced Phase Equilibria (LEC 3.0)
Advanced aspects of unary, binary and ternary organic, phase equilibria. Includes practical examples of the applications of phase diagrams to solve engineering problems. Prerequisite: Graduate standing.

MS&E 5230 Energy Materials (LEC 3.0)
The objectives of the course are to understand how the rational design and improvement of chemical and physical properties of materials can lead to energy alternatives that can compete with existing technologies. Discussions on the present and future energy needs from a view point of multidisciplinary scientific and technological approaches. Prerequisite: Senior standing.

MS&E 5310 Biomaterials I (LEC 3.0)
This course will introduce senior undergraduate students to a broad array of topics in biomaterials, including ceramic, metallic, and polymeric biomaterials for in vivo use, basic concepts related to cells and tissues, host reactions to biomaterials, biomaterials-tissue compatibility, and degradation of biomaterials. Prerequisites: Senior undergraduate standing. (Co-listed with BIO SCI 5210, CHEM ENG 5200).

MS&E 5460 Molecular Engineering of Materials (LEC 3.0)
This course focuses on the fundamentals of molecular engineering with an emphasis on their applications including renewable/clean energy solutions, energy storage, air/water cleaning, and optoelectronics. Topics include principles of modern physics, carbon chemistry, macromolecules, metal(covalent)-organic frameworks sol-gel processing and crystal growth. Prerequisites: Senior Standing or consent of instructor. (Co-listed with Chem 5460).

MS&E 5517 Materials Selection in Mechanical Design (LEC 3.0)
This course will introduce the basics of materials selection in mechanical design. It will also introduce the benefits of computational materials and process selection. The students will also learn to use a commercially available materials selection software. This course will be offered as Distance Ed. Prerequisite: Met Eng 2110.

MS&E 5810 Introduction to Polymeric Materials (LEC 3.0)
A basic study of the organic chemistry of natural and synthetic high polymers, their inherent properties and their uses in plastic, fiber, rubber, resin, food, paper and soap industries. Credit may not be given for both Chem 5810 and Chem 4810. Prerequisite: Chem 1320. (Co-listed with Chem 5810 and Chem Eng 5810).

MS&E 5819 Polymer Synthesis and Characterization Lab (LAB 1.0)
Laboratory experiments dealing with polymerization syntheses and solution, bulk and solid properties will be presented. Each student will prepare polymers and carry out all characterization experiments on actual samples. Credit may not be given for both Chem 5819 and Chem 4819. Prerequisite: Chem 4810 or MS&E 4810 or Chem 5810 or MS&E 5810 or Chem Eng 5310, preceded or accompanied by Chem 1100 or Chem 5100 or an equivalent training program approved by S&T. (Co-listed with Chem 5819).

MS&E 5850 Introduction to Coating Chemistry (LEC 3.0)
Study of the basic principles of protective coatings with particular reference to the paint and varnish industry. Classifications, manufacture, properties and uses of protective coatings. Credit may not be given for both Chem 5850 and Chem 4850. Prerequisite: Chem 1320 or Met Eng 1210. (Co-listed with Chem 5850).

MS&E 6000 Special Problems (IND 0.0-6.0)
Problems or readings on specific subjects or projects in the department. Consent of instructor required.

MS&E 6001 Special Topics (LEC 0.0-6.0)
This course is designed to give the department an opportunity to test a new course. Variable title.

MS&E 6010 Seminar (RSD 0.0-6.0)
(Variable) Discussion of current topics.

MS&E 6050 Continuous Registration (IND 1.0)
Doctoral candidates who have completed all requirements for the degree except the dissertation and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

MS&E 6060 Advanced Chemistry of Construction Materials (LEC 3.0)
To describe fundamental composition-reactivity-microstructure-property relationships in construction materials. Tests will include quizzes, written-exams, as well as a term paper and a presentation on a topic relevant to the course.

MS&E 6085 Internship (IND 0.0-15)
(Variable) Students working toward a doctor of engineering degree will select with the advice of their committees, appropriate problems for preparation of a dissertation. The problem selected and internship plan must conform to the purpose of providing a high level engineering experience consistent with the intent of the doctor of engineering degree.

MS&E 6099 Research (IND 0.0-15)
(Variable) Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

MS&E 6110 Bonding, Crystallography, and Structure-Property Relationships (LEC 3.0)
Principles of electronic structure and chemical bonding in solids and their relationships to electrical, mechanical, thermal, and optical properties. An exploration of reciprocal lattices and tensor properties of crystals; consideration of the impact of crystal symmetry on anisotropy. The influence of defects and grain boundary phenomena on material behavior. Prerequisite: Graduate standing, or undergraduate standing with instructor and advisor approval.

MS&E 6120 Thermodynamics and Phase Equilibria (LEC 3.0)
Classical thermodynamic treatment of materials and material processing based on the 1st and 2nd Laws of Thermodynamics and phase equilibria considerations. The course will cover equilibria in gaseous systems, gas-solid reactions including passive and active oxidation, solution thermodynamics, phase equilibria in solution systems, and electrochemistry. Prerequisite: Graduate standing, or undergraduate standing with instructor and advisor approval.

MS&E 6130 Kinetic Theory for Materials (LEC 3.0)
Phenomenological and atomistic theories of diffusion in materials including discussion of short circuit diffusion and ionic diffusion in an electric field. Fundamentals of phase transformation in materials; chemical fluctuation, nucleation and growth theory; kinetic models for evaluating and predicting diffusion controlled transformation kinetics. Prerequisite: Graduate standing, or undergraduate standing with instructor and advisor approval.

MS&E 6210 Advanced Tissue Engineering (LEC 3.0)
The course will introduce graduate students to the principles and clinical applications of tissue engineering including the use biomaterials, scaffolds, cells, and external factors to develop implantable parts for the restoration, maintenance, or replacement of tissues and organs. A related topic term paper and oral presentation are expected. Prerequisite: Graduate standing. (Co-listed with Bio Sci 6240).

MS&E 6220 Advanced Energy Materials (LEC 3.0)
The objectives of the graduate level course are to review the recent developments on advanced energy materials and systems in addition to basic understanding how chemical and physical properties of materials can lead to energy alternatives. Prerequisite: Graduate standing.

MS&E 6230 Nanomaterials (LEC 3.0)
Introduction of the fundamentals of nanomaterials and recent developments on nanomaterials. Topics include physical and chemical properties, synthesis, processing, and applications of nanomaterials. Example nanomaterials include nanoparticles, nanotubes, and nanowires. Students will need to complete a project related to nanomaterials. Prerequisite: Graduate Standing. (Co-listed with Chem Eng 6310).

MS&E 6310 Biomaterials II (LEC 3.0)
This course will introduce graduate students to a broad array of topics in biomaterials, including ceramic, metallic, and polymeric biomaterials for in vivo use, basic concepts related to cells and tissues, host reactions to biomaterials, biomaterials-tissue compatibility, and degradation of biomaterials. A term paper and oral presentation are required. (Co-listed with BIO SCI 6210, CHEM ENG 6300).

MS&E 6460 Advanced Molecular Engineering of Materials (LEC 3.0)
This advanced course focuses on the fundamentals of molecular science and engineering and their applications including renewable/clean energy solutions, energy storage, and optoelectronics. Topics include principles of carbon chemistry, macromolecules, metal(covalent)-organic frameworks, sol-gel processing, crystal growth and other advanced topics. Prerequisites: Graduate Standing or consent of instructor. (Co-listed with CHEM 6460).

MS&E 6820 Polymer Synthesis (LEC 3.0)
The methods of organic monomer and polymer syntheses will be explored. Mechanistic and structural components, modern and current industrial methods for polymer syntheses will be discussed. Topics include linear, branched, graft, and dendritic polymers, nano-technology and macromers. Prerequisites: Chem 4810 or MS&E 4810 or Chem 5810 or MS&E 5810; Chem 2220 or Chem 4210 or Chem 4220 or Chem 5210 or Chem 5220. (Co-listed with Chem 6820).

MS&E 6840 Polymer Physical Chemistry and Analysis (LEC 3.0)
A study of the physical properties of macromolecular systems including polymer solutions, gels, bulk polymers and rubbers. The chemical characterization of polymers based on their thermal, spectroscopic, microstructure and molecular weight is also discussed. Prerequisite: Chem 4810 or MS&E 4810 or Chem 5810 or MS&E 5810; thermodynamics. (Co-listed with Chem 6840).
