MATERIALS SCIENCE AND ENGINEERING

The Materials Science and Engineering Program for professionals allows students to take courses that address current and emerging areas critical to the development and use of biomaterials, electronic materials, structural materials, nanomaterials and nanotechnology, and related materials processing technologies. Students in this program gain an advanced understanding of foundational concepts and are exposed to the latest research that is driving materials-related advances.

Program Committee

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Programs

- Materials Science and Engineering, Master of Science (https://e-catalogue.jhu.edu/engineering/engineering-professionals/materials-science-engineering/materials-science-engineering-master-science/)

Courses

EN.515.601. Structure and Properties of Materials. 3 Credits.
Topics include types of materials, bonding in solids, basic crystallography, crystal structures, tensor properties of materials, diffraction methods, crystal defects, and amorphous materials.

EN.515.602. Thermodynamics and Kinetics of Materials. 3 Credits.
Topics include laws of thermodynamics, equilibrium of single and multiphase systems, chemical thermodynamics, statistical thermodynamics of solid solutions, equilibrium phase diagrams, chemical kinetics, diffusion in solids, nucleation and growth processes, coarsening, and glass transition.

EN.515.603. Materials Characterization. 3 Credits.
This course will describe a variety of techniques used to characterize the structure and composition of engineering materials, including metals, ceramics, polymers, composites, and semiconductors. The emphasis will be on microstructural characterization techniques, including optical and electron microscopy, x-ray diffraction, and acoustic microscopy. Surface analytical techniques, including Auger electron spectroscopy, secondary ion mass spectroscopy, x-ray photoelectron spectroscopy, and Rutherford backscattering spectroscopy. Real-world examples of materials characterization will be presented throughout the course, including characterization of thin films, surfaces, interfaces, and single crystals.

EN.515.605. Electrical, Optical and Magnetic Properties. 3 Credits.
An overview of electrical, optical and magnetic properties arising from the fundamental electronic and atomic structure of materials. Continuum materials properties are developed through examination of microscopic processes. Emphasis will be placed on both fundamental principles and applications in contemporary materials technologies.Course Note(s): Please note that this 515 course is also listed as a 510 course in the full-time program. It is the same course. Part-time students should register for the 515 course.
Prerequisite(s): EN.515.601 or equivalent.

EN.515.606. Chemical and Biological Properties of Materials. 3 Credits.
An introduction to the chemical and biological properties of organic and inorganic materials. Topics include an introduction to polymer science, polymer synthesis, chemical synthesis, and modification of inorganic materials, biomineralization, biosynthesis, and properties of natural materials (proteins, DNA, and polysaccharides), structure-property relationships in polymeric materials (synthetic polymers and structural proteins), and materials for biomedical applications. Course Note(s): Please note that this 515 course is also listed as a 510 course in the full-time program. It is the same course. Part-time students should register for the 515 course. Recommended Course Background: undergraduate chemistry and biology or permission of instructor.

EN.515.607. Introductory Biomaterials. 3 Credits.
This course offers an overview of the structure-property relationship for metal, ceramic, and polymeric materials commonly used in biomedical applications. Differences in material properties between these synthetic materials and native biologic materials and the biological consequences of these differences will also be identified.

EN.515.608. Biomaterials II: Host Response and Biomaterials Applications. 3 Credits.
This course focuses on the interaction of biomaterials with the biological system and applications of biomaterials. Topics include host reactions to biomaterials and their evaluation, cell-biomaterials interaction, biomaterials for tissue engineering applications, biomaterials for controlled drug and gene delivery, biomaterials for cardiovascular applications, biomaterials for orthopedic applications, and biomaterials for artificial organs. Course Note(s): Please note that this 515 course is also listed as a 510 course in the full-time program. It is the same course. Part-time students should register for the 515 course.

EN.515.611. Computational Molecular Dynamics. 3 Credits.
This course aims to enable the student to understand and predict properties of microscopic systems in materials science, physics, biology, and chemistry. We will cover the basics of molecular simulation methods, and provide an overview of modeling tools for problems of interest. In particular this course will cover both hard and soft matter materials spaces. The course is geared toward students with an interest in molecular modeling, with or without prior experience in the area. At the end of this course, students should have a general knowledge of current state-of-the-art molecular simulation methods, and be able to design, run, and analyze simulations for systems of interest.

EN.515.615. Physical Properties of Materials. 3 Credits.
A detailed survey of the relationship between materials properties and underlying microstructure. Structure/property/ processing relationships will be examined across a wide spectrum of materials including metals, ceramics, polymers and biomaterials, and properties including electrical, magnetic, optical, thermal, mechanical, chemical and biocompatibility. Course Note(s): Please note that this 515 course is also listed as a 510 course in the full-time program. It is the same course. Part-time students should register for the 515 course.

EN.515.616. Introduction To Nanotechnology. 3 Credits.
Nanoscale science and nanotechnology are broad, interdisciplinary areas, encompassing not just materials science but everything from biochemistry to electrical engineering and more. This will be a survey course introducing some of the fundamental principles behind nanotechnology and nanomaterials, as well as applications of nanotechnology. The role of solid-state physics and chemistry in nanotech will be emphasized. Nanoscale tools such as surface probe and atomic force microscopy, nanolithography, and special topics such as molecular electronics will also be covered.

EN.515.617. Nanomaterials. 3 Credits.
Nanomaterials is a survey course that covers concepts and the associated relevant physics and materials science of what makes nanoscale materials so unique. We'll learn about nanoscale characterization (electron and probe microscopy), fabrication at the nanoscale (self-assembly and top-down fabrication), and many current applications of nanomaterials across broad areas from medicine to defense. This course will take an in-depth look at nanomaterials discussed in Introduction to Nanotechnology; however, it stands alone with no prerequisite.

EN.515.620. Nanoparticles. 3 Credits.
Nanoparticles - one-dimensional materials with diameters of nearly atomic dimension - are one of the most important classes of nanostructured materials because their unusual properties that often differ significantly from bulk materials. This course will explore the synthesis, structure and properties of nanoparticles. Applications of nanoparticles in medicine, optics, sensing, and catalysis will be discussed, with an emphasis will be on metal nanoparticles and semiconductor quantum dots. Course Note(s): Part-time students should register for the 515 course.

EN.515.621. Biomolecular Materials I: Soluble Proteins & Amphiphiles. 3 Credits.
Structure and function of cellular molecules (lipids, nucleic acids, proteins, and carbohydrates). Structure and function of molecular machines (enzymes for biosynthesis, motors, pumps). Protein synthesis using recombinant nucleic acid methods. Advanced materials development. Interactions of biopolymers, lipid membranes, and their complexes. Mean field theories, fluctuation and correlation effects. Self assembly in biomolecular materials. Biomedical applications. Characterization techniques.

EN.515.622. Micro and Nano Structured Materials & Devices. 3 Credits.
Almost every material's property changes with scale. We will examine ways to make micro- and nano-structured materials and discuss their mechanical, electrical, and chemical properties. Topics include the physics and chemistry of physical vapor deposition, thin film patterning, and microstructural characterization. Particular attention will be paid to current technologies including computer chips and memory, thin film sensors, diffusion barriers, protective coatings, and microelectromechanical (MEMS) devices Course Note(s): Part-time students should register for the 515 course.

EN.515.627. Chemistry of Nanomaterials. 3 Credits.
This course introduces the fundamental principles necessary to understand the behavior of materials at length scales larger than atoms or molecules with applications in chemistry and materials science. This course will explore topics such as nanoparticle synthesis and self assembly, ordered porous materials, catalysis, nanostructured thin films, and solar energy conversion. Size dependent properties of nanomaterials will be discussed.

EN.515.628. Introduction to Solid State Chemistry. 3 Credits.
This course focuses on understanding materials properties and their impact on engineering systems. Students in this course will explore the interrelationships among the atomic structure, bonding, and defects, and their influence on the electrical, magnetic, and optical properties of materials. This course will cover topics related to: atomic arrangement; synthesis and processing of materials; characterization using x-ray, thermal and electrochemical methods; specialized topics involving real-world examples drawn from industry including semiconductor processing, energy conversion and storage, and emerging materials-specific technologies.

EN.515.634. Fundamentals of Metamaterials. 3 Credits.
This course introduces the student to the field of metamaterials. The course will begin with a review of basic electromagnetic wave propagation and interaction with matter. The remainder of the course will discuss how metamaterials can be utilized to manipulate electromagnetic fields. Topics will include negative refractive index, perfect lensing, metasurfaces, artificial magnetic conductors, and absorbers.

EN.515.635. Mechanical Properties of Materials. 3 Credits.
This course will consist of a detailed study of the mechanical properties of materials. Topics covered will include stress-strain behavior, elastic and plastic deformation mechanisms, failure mechanisms in quasi-static and dynamic loading conditions, and microstructure-properties relationships. These topics will be discussed as applied to metallic, ceramic, polymeric, and composite materials at bulk and nano scales. The course will also introduce destructive and non-destructive mechanical testing methods. Course Note(s): Please note that this 515 course is also listed as a 510 course in the full-time program. It is the same course. Part-time students should register for the 515 course.

EN.515.636. Chemical Synthesis and Processing of Advanced Materials. 3 Credits.
This is a treatise course on chemical processing of materials. The primary objective of this course is to provide an introduction to various chemical synthesis and formulation techniques for the study of advanced materials including metals, alloys, semiconductors, ceramics, carbons, polymers, coatings, thin films, nanoparticles, and nanostructured materials. The course will discuss both established chemical processing methods and recent advances in materials synthesis and fabrication. Other topics to be covered include thermodynamics and kinetics in chemistry, structure-property relations, and materials characterization techniques.

EN.515.640. Stealth Science and Engineering. 3 Credits.
The goal of stealth engineering is the creation of objects that are not easily detected using remote sensing techniques. To achieve this end, engineered systems of materials are arrayed to alter the signature of objects by reducing energy returned to remote observers. This course will provide an introduction to the general principles behind signature reduction by examining the mathematics and science behind basic electromagnetic and acoustic transport processes. Specific topics will include energy absorbing materials, anti-reflection coatings, wave guiding and scattering, metamaterials and adaptive screens.

EN.515.646. Artificial Intelligence Methods for Materials Science. 3 Credits.
This course will introduce the principles of machine learning and data science, with a focus on applications in materials science. The fundamentals of machine learning will be emphasized along with state-of-the-art techniques. Topics include data visualization, train/test splits, cross-validation, boosting models and convolutional neural networks. Real-world materials science datasets will be used throughout, and different data formats will be considered (e.g., descriptors vs. images). Students will demonstrate their knowledge in a final project that uses data derived from actual applications.

EN.515.651. Manufacturing Materials and Processes. 3 Credits.
Manufacturing Materials and Processes is a comprehensive survey course that presents materials behaviors as constraints that direct manufacturing processes. Mechanical, physical, and phase change properties of metallics, polymers, and ceramics constrain the methods of forming these materials into engineering commodities. Phase diagrams, work hardening of metallics, thermal treatments of solids, powder metallurgy, and composite material designs are explored. The major methods of shaping and treating engineering materials to optimize their uses are presented. Metal casting, glass working, polymer processing, composite materials assembly, powder metallurgy forming, bulk deformation shaping, sheet metal forming, machining operations, and additive manufacturing are examined. The origins, avoidance, and consequences of manufacturing discontinuities and defects are examined. Techniques for nondestructive evaluation of latent defects are detailed. Competitive global manufacture and economic impacts of local manufacturing are highlighted.

EN.515.654. Introduction to Micro- and Nano-fabrication. 3 Credits.
This course covers the principles of micro(nano)-fabrication processes for creation of electronic/optical/mechanical devices. The course exposes students to clean room etiquette and safety, film deposition, lithography, etching (dry/wet), vacuum systems, oxide growth, etc. and will familiarize students with use of various techniques, systems and equipment commonly encountered in microfabrication facilities. This course also introduces students to various characterization techniques by introducing concepts such as crystallography/semiconductor physics and electromagnetism/optics/microscopy at an introductory level. The course includes the necessary background for students so they can specify fabrication processes for particular device designs.

EN.515.655. Metal Additive Manufacturing. 3 Credits.
Additive Manufacturing (AM), also known colloquially as 3D Printing, is a disruptive technology that has received significant attention in recent years in both the popular press and the manufacturing industry. While the current and potential future applications for this technology, especially for mission-critical metal parts, are impressive and imaginative, the full potential for metal AM has not been realized due to current limitations and a lack of full understanding of metal AM processes. In this class we will cover (1) the current state-of-the-art of AM; (2) the production steps necessary to manufacture AM parts; and (3) the closely linked topics of AM materials and AM processes. While non-metal AM materials such as polymers, composites, and ceramics will be included, the primary focus will be on metal materials fabricated with laser powder bed fusion processes. Specific topics covered will include conventional vs. AM materials, meltpool phenomena including solidification, kinetics and solid-state kinetics, post-process thermal treatments, the process-properties relationship, in-situ process sensing, indirect process measurement methods and process modeling. Recent implementations of metal additive manufacturing, such as those in the aerospace and health care industries, will be presented extensively throughout the class as study cases. Popular press articles and technical papers on AM will be reviewed and discussed. Students taking this class will be expected to participate actively and bring to the class real or potential applications of AM in their workplaces.

EN.515.658. Design for Additive Manufacturing. 3 Credits.
This class builds on material covered in the Additive Manufacturing (AM) overview class (515.656) and previous Materials Science and Engineering courses such as Thermodynamics and Kinetics of Materials (515.602). We will learn the design process and design for AM specifically. Students will determine applications and opportunities to apply AM technology and also learn how to evaluate AM designs. Topics will include work flow decisions to determine AM application, design considerations for metal and polymer AM, design for multi-material and functional assembly applications, and AM design evaluation.
Prerequisite(s): EN.515.655 Metal Additive Manufacturing

EN.515.661. Introduction to Polymer Science. 3 Credits.
The goal of this course is to provide students with an introduction to the preparation, properties and manufacturing of polymers. Methods for synthesizing polymers, manufacture of polymers and the techniques used to characterize polymer properties will be presented. The course topics include natural and synthetic giant molecules; inorganic and organic polymers; biomacromolecules; and elastomers, adhesives, coatings, fibers, plastics, blends, caulks, composites, and ceramics. The basic principles that apply to one polymer class can be used to understand all of the other classes and are integrated into the framework of this course.

EN.515.730. Materials Science and Engineering Project. 3 Credits.
This course is an individually tailored, supervised project that offers research experience through work on a special problem related to each student's field of interest. Upon completion of this course, a written essay must be submitted. The faculty advisor will approve the final essay. All other coursework should be completed before this project begins (or at least completed concurrently with this project). Consent of advisor is required.

EN.515.731. Materials Science and Engineering Project. 3 Credits.
This course is an individually tailored, supervised project that offers research experience through work on a special problem related to each student's field of interest. Upon completion of this course, a written essay must be submitted. The faculty advisor will approve the final essay. All other coursework should be completed before this project begins (or at least completed concurrently with this project). Consent of advisor is required.

EN.515.800. Independent Study in Materials Science and Engineering. 3 Credits.
Independent study allows students to take a specialty course on a topic not currently offered within EP but is related to the expertise of a faculty member. Students enrolled in this course are expected to meet with their instructor on a weekly basis and to complete assignments as required including but not restricted to homework, tests and topical essays. Arrangements for this course should be made between the student and the instructor. Final approval is required from the Program Chair. Generally, only one semester of Independent Study will be approved, but a second semester will be granted with justification. All other coursework should be completed before this project begins (or at least completed concurrently with this project). Program Chair approval is required.

EN.515.801. Independent Study in Material Science and Engineering. 3 Credits.
Second semester of independent study. See description for EN.515.800.