## Materials Science and Engineering (MAT)

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### Prerequisites

- **MAT 033**: For MAT 020, 028, 201, 203, 204, 205, 206, 214, 216, 218.
- **PHY 009 or PHY 010 or PHY 011**: For MAT 033, 101.
- **ENG 100**: For MAT 028.
- **MAT 033 and MATH 205**: For MAT 204.
- **CHM 030 and MATH 033**: For MAT 204.
- **MATH 023 and MATH 033**: For MAT 205.
- **MATH 023, MATH 033, and MATH 205**: For MAT 206.
- **MATH 201 and MATH 203**: For MAT 204.
- **MATH 204 and MATH 206**: For MAT 206.
- **MATH 204 and MATH 206**: For MAT 214.
- **MATH 204 and MATH 206**: For MAT 218.
- **MATH 204 and MATH 206**: For MAT 216.
- **MATH 201**: For MAT 204.
- **MATH 201 and MATH 203**: For MAT 214.
- **PHYS 009 and PHYS 010 or PHYS 011**: For MAT 033.
- **MATH 010**: For MAT 204.
- **MATH 033 and MATH 010**: For MAT 204.
- **MATH 033 and MATH 010**: For MAT 205.
- **MATH 023 and MATH 033**: For MAT 206.
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- **MATH 023 and MATH 033**: For MAT 226.
- **MATH 023 and MATH 033**: For MAT 300.
- **MATH 023 and MATH 033**: For MAT 309.
- **MATH 023 and MATH 033**: For MAT 310.

### Repeat Status
- **MAT 204**: Course may be repeated.
MAT 312 Fundamentals of Corrosion 3 Credits
Prerequisites: MAT 205 or CHM 342

MAT 314 (ME 314) Metal Forming Processes 3 Credits
Prerequisites: MAT 206

MAT 315 Physical Properties of Structural and Electronic Ceramics 3 Credits
Structure-property relationships in ceramics. Mechanical behavior including plasticity, hardness, elasticity, strength and toughening mechanisms. Thermal behavior including specific heat, thermal expansion, thermal conduction and thermal shock. Electrical behavior including application of tensors and crystal physics to electroceramics.
Prerequisites: MAT 214

MAT 316 Optical Properties of Materials 3 Credits
Interaction of electromagnetic waves with solid, liquid, and gaseous matter: reflection, refraction, polarization, diffraction, scattering, absorption, and luminescence. Factors determining the perceived color of metals, ceramics, polycrystals, semiconductors, biomaterials, and various nanostructured materials. Overview of the technological applications of optical materials in coatings, lighting, display technologies, lasers, solar cells, and optical communications. Credit will not be given for both MAT 316 and MAT 416.
Prerequisites: MAT 033

MAT 317 Imperfections in Crystals 3 Credits
The major types of crystal defects and their role in controlling the properties of materials. Point, line and planar defects, their atomic configurations and experimental techniques to study their characteristics. Emphasis on the role of dislocations and grain boundaries in the control of mechanical properties.
Prerequisites: MAT 203

MAT 319 Current Topics in Materials Science 3 Credits
Selected topics of current interest in the field of materials engineering but not covered in the regular courses. Consent of department required.

Repeat Status: Course may be repeated.

MAT 320 Analytical Methods in Materials Science 3 Credits
Selected topics in modern analysis and their application to materials problems in such areas as thermodynamics, crystallography, deformation and fracture, diffusion.
Prerequisites: MATH 231 or MATH 205

MAT 324 (BIOE 324) Introduction to Organic Biomaterials 3 Credits
Property, characterization, fabrication and modification of organic materials for biomedical and biological applications; host responses to biomaterials on the molecular, cellular and system level; general introduction to biosensors, drug delivery devices and tissue engineering. Consent of instructor required.
Prerequisites: BIOE 110 or MAT 204

MAT 325 (BIOE 325) Inorganic Biomaterials 3 Credits
Fabrication methods for biomedical implant and devices. Selection of metals and ceramics with specific bulk and surface physical as well as chemical properties. The role of materials chemistry and microstructure. Biocompatibility. Case studies (dental and orthopedic implants, stents, nonporous ceramic filters for kidney dialysis).
Prerequisites: MAT 033

MAT 326 (BIOE 326) Biomimetic and Bio-enabled Materials 3 Credits
The structure, function, properties and use of biopolymers, biocomposites, and biominerals. Biomimetic materials design, including colloids, interfaces, macromolecules, and applications of such materials. Environmental and ethical considerations, such as degradation products when using biomimetic materials. Closed to students who have taken MAT 426 (BioE 426).
Prerequisites: MAT 033 or BIOE 110

Attribute/Distribution: ND

MAT 327 Industrial Project 4 Credits
Restricted to a small group of seniors and graduate students selected by the department from those who apply. Two full days per week are spent on development projects at the plant of an area industry, under the direction of a plant engineer and with faculty supervision.

MAT 329 Industrial Project 4 Credits
To be taken concurrently with MAT 327. Material is the same as MAT 327.

MAT 332 Basics of Materials Science and Engineering 3 Credits
Physical and chemical principles applied to understanding the structure, properties, selection, fabrication, and use of engineering materials: metals, polymers, ceramics, composites and electronic materials. Case studies of materials used ranged from transportation systems to microelectronic devices. Lectures and individual study assigned by graduate advisor. Must have graduate student status. Consent of department required. Not available to students who have taken MAT 033 or equivalent.

MAT 333 Crystallography and Diffraction 3 Credits
Introduction to crystal symmetry, point groups, and space groups. Emphasis on materials characterization by x-ray diffraction and electron diffraction. Specific topics include crystallographic notation, stereographic projections, orientation of single crystal, textures, phase identification, quantitative analysis, stress measurement, electron diffraction, ring and spot patterns, convergent beam electron diffraction (CBED), and space group determination. Applications in mineralogy, metallurgy, ceramics, microelectronics, polymers, and catalysts. Lectures and laboratory work. Senior standing in chemistry.
Prerequisites: MAT 203 or EES 133

MAT 334 (CHE 334) Electron Microscopy and Microanalysis 4 Credits
Fundamentals and experimental methods in electron optical techniques including scanning electron microscopy (SEM), conventional transmission (TEM) and scanning transmission (STEM) electron microscopy. Specific topics covered will include electron optics, electron beam interactions with solids, electron diffraction and chemical microanalysis. Applications to the study of the structure of materials are given. Consent of department required.

MAT 340 Research Techniques 3 Credits
Study and application of research techniques in materials science and engineering. Research opportunities, design of experimental programs, analysis of data, presentation of results. Selection of research topic and preparation and defense of research proposal. Restricted to a small number of students selected by the department from those who apply.

MAT 341 Undergraduate research 3 Credits
Application of research techniques to a team-based project in materials science and engineering selected in consultation with the faculty and advised by at least one faculty member in Materials Science and Engineering. Thesis writing in consultation with faculty advisor and mentors. Preceded by MAT 340. Department permission required.

MAT 342 Inorganic Glasses 3 Credits
Definition, formation and structure of glass; common glass systems; manufacturing processes; optical, mechanical, electrical and dielectric properties; chemical durability; glass fibers and glass ceramics. Lectures and laboratories.
Prerequisites: MAT 033
MAT 345 Additive Manufacturing and Powder Metallurgy 3 Credits
Application of powder metallurgy in emerging technologies in the field of Additive Manufacturing (aka 3-D Printing). Metal powder fabrication and characterization methods. Powder processing including powder compaction, theory of compacting, press and die design, sintering, hot consolidation and additive manufacturing. Microstructure and properties of sintered materials and their relationship to processing conditions. Industrial applications. Emerging powder metallurgy technologies. Credit will not be given for both MAT 345 and MAT 445.
Prerequisites: MAT 206 or ISE 215 or ME 240

MAT 346 Physical Metallurgy of Welding 3 Credits
Prerequisites: MAT 216

MAT 355 Materials for Nanotechnology 3 Credits
An introduction to the nanoworld and how we observe the nanoworld through transmission electron microscopy. Other topics include: probing nanosurfaces, carbon as a nanomaterial, fullerenes, carbon nanotubes, metal clusters, metal nanoparticle preparation, and directed self-assembly of nanoparticles. Also discussed are the thermal, chemical, electronic, optical, and magnetic properties of metal nanoparticles, nanowires, semiconductor nanoparticles, and inorganic nanoparticles.

MAT 356 Strategies for Nanocharacterization 3 Credits
Lectures describe various nanocharacterization techniques in terms of which technique is best for specific measurements on nanostructures less than 100 nm in extent. Special attention is paid to spatial resolution and detection limits for SEM, TEM, X-ray analysis, diffraction analysis, ion beam techniques, surface techniques, AFM and other SPMs, and light microscopies and spectroscopies.

MAT 357 Thin Film Deposition, Processing, and Characterization 3 Credits
Thin films are at the heart of electronics, optics, medicine, and nanotechnology. Fundamental and applied aspects of thin film deposition, processing, and characterization. Growth methods including physical and chemical deposition techniques. Equipment and hardware for deposition and analysis. Structural, mechanical, electronic, and chemical properties of films. Processing methods and their relationship to specific applications.
Prerequisites: MAT 033

MAT 363 Computational Methods in Science and Engineering 3 Credits
Computer simulation of systems at various length and time scales. Atomistic simulation (molecular dynamics and Monte Carlo) methods are presented and applied to models described by simple interatomic potentials. Mesoscale simulation is described in the context of domain growth and, at the continuum scale, finite-difference and finite-element methods are employed to model heat conduction and mass diffusion. Lecture and computer laboratory sessions. Credit will not be given for both MAT363 and MAT463.

MAT 386 Polymer Nanocomposites 3 Credits
Synthesis, morphology and properties of polymer nanocomposites. Comparisons with traditional particulate composites will be made and models predicting properties will be emphasized. Melt viscosity, mechanical properties, barrier properties and flame retardancy will be discussed. Credit is not given for both MAT 386 and MAT 486.
Prerequisites: MAT 204 or MAT 393

MAT 388 (CHE 388, CHM 388) Polymer Synthesis and Characterization Laboratory 3 Credits
Techniques include: free radical and condensation polymerization; molecular weight distribution by gel chromatography; crystallinity and order by differential scanning calorimetry; pyrolysis and gas chromatography; dynamic mechanical and dielectric behavior; morphology and microscopy; surface properties. Must have senior level standing in chemical engineering, chemistry, or materials science and engineering.
Prerequisites: CHM 341 and CHM 110

MAT 392 (CHE 392) Introduction to Polymer Science 3 Credits
Introduction to concepts of polymer science. Kinetics and mechanism of polymerization, synthesis and processing of polymers, characterization. Relationship of molecular conformation, structure and morphology to physical and mechanical properties.

MAT 393 (CHE 393, CHM 393) Physical Polymer Science 3 Credits
Structural and physical aspects of polymers (organic, inorganic, natural). Molecular and atomic basis for polymer properties and behavior. Characteristics of glassy, crystalline, and paracrystal-line states (including viscoelastic and relaxation behavior) for single- and multi-component systems. Thermodynamics and kinetics of transition phenomena. Structure, morphology, and behavior. Available to graduate and undergraduate students (with senior level standing) in CHE, CHEM or MAT.

MAT 401 Thermodynamics and Kinetics 4 Credits
Integrated treatment of the fundamentals of thermodynamics, diffusion and kinetics, as related to materials processes including both hard and soft materials. Laws of thermodynamics, conditions of equilibrium, free energies, statistical thermodynamics, thermodynamics of surfaces, bulk and grain-boundary diffusion, nucleation, spinodal decomposition, and reaction kinetics.

MAT 402 (ME 402) Advanced Manufacturing Science 3 Credits
The course focuses on the fundamental science-base underlying manufacturing processes, and applying that science base to develop knowledge and tools suitable for industrial utilization. Selected manufacturing processes representing the general classes of material removal, material deformation, material phase change, material flow, and material joining are addressed. Students create computer-based process simulation tools independently as well as utilize leading commercial process simulation packages. Laboratory experiences are included throughout the course.

MAT 403 Structure/Property Relations 4 Credits
Structure of materials and relationship to properties. Crystal structures and crystalline defects, structure in biological systems, amorphous materials, microstructure, and relationships to mechanical and other properties.

MAT 406 Solidification 3 Credits
Structure, theory and properties of liquids. Homogeneous and heterogeneous nucleation theory and experimental results. Solidification phenomena in pure, single and multiphase materials including the nature of the freezing interface, segregation, constitutional super-cooling, dendritic growth, crystallographic effects, the origin of defects, crystal growing, zone processes. Consent of department chair required.

MAT 409 Current Topics in Materials 3 Credits
Recent practical and theoretical developments in materials. This course may be repeated for credit if new material is covered. Consent of department required.
Repeat Status: Course may be repeated.

MAT 414 Metal Forming Processes 3 Credits
Prerequisites: MAT 206
MAT 415 Mechanical Behavior of Ceramic Solids 3 Credits
Strength, elasticity, creep, thermal stress fracture, hardness, abrasion and high-temperature deformation characteristics of single- and multicomponent brittle ceramic solids. Statistical theories of strength, static and cyclic fatigue, crack propagation, fracture toughness. Correlation of mechanical behavior, microstructure, and processing parameters.

MAT 416 Optical Properties of Materials 3 Credits
Interaction of electromagnetic waves with solid, liquid, and gaseous matter: reflection, refraction, polarization, diffraction, scattering, absorption, and luminescence. Factors determining the perceived color of metals, ceramics, polymers, semiconductors, biomaterials, and various nanostructured materials. Overview of the technological applications of optical materials in coatings, lighting, display technologies, lasers, solar cells, and optical communications. Additional coursework will be required of students seeking the graduate level MAT 416 qualification. Credit will not be given for both MAT 316 and MAT 416.
Prerequisites: MAT 033

MAT 423 Advanced Transmission Electron Microscopy 4 Credits
The theory and practice of operation of the transmission and scanning transmission electron microscope. Techniques covered include bright field, high resolution and weak-beam dark field, lattice imaging, diffraction pattern indexing and Kikuchi line analysis. The theory of diffraction contrast is applied to the interpretation of electron micrographs. Specimen preparation techniques.
Prerequisites: MAT 344

MAT 424 (BIOE 424) Introduction to Organic Biomaterials 3 Credits
Property, characterization, fabrication, and modification of organic materials for biomedical and biological applications; host responses to biomaterials on the molecular, cellular, and system level; general introduction to biosensors, drug delivery, and tissue engineering. Graduate version of MAT 324 requiring additional assignments. Credit is not given for both MAT 324 (BioE 324) and MAT 424 (BioE 424).
Prerequisites: MAT 033

MAT 425 (BIOE 425) Inorganic Biomaterials 3 Credits
Fabrication methods for biomedical implant and devices. Selection of metals and ceramics with specific bulk and surface physical as well as chemical properties. The role of materials chemistry and microstructure. Biocompatibility. Case studies (dental and orthopedic implants, stents, nonporous ceramic filters for kidney dialysis). Graduate version of MAT 325; credit will not be given for both MAT 325 and MAT 425.
Prerequisites: MAT 033

MAT 426 (BIOE 426) Biomimetic and Bio-enabled Materials 3 Credits
This course is a graduate version of MAT 326 (BIOE 326). While the lecture content will be the same as the 300-level course, students enrolled in MAT 426 (BIOE 426) will have more advanced assignments. Closed to students who have taken MAT 326 (BIOE 326). Requirements: Graduate standing in Bioengineering or Materials Science and Engineering. Attribute/Distribution: ND

MAT 427 Advanced Scanning Electron Microscopy 4 Credits
The theory and practice of operation of the scanning electron microscope and electron microprobe. Techniques covered will include high-resolution scanning, quantitative electron probe microanalysis. Electron beam sample interactions, X-ray spectrometry, and electron optics will be discussed in detail.
Prerequisites: MAT 334

MAT 430 Glass Science 3 Credits
Definition and formation of glass. Structure of common inorganic (including metallic) and polymeric glass systems. Methods of glass melting. Phase separation of devitrification. Physical properties including diffusion, electrical conductivity, chemical durability, and optical and mechanical properties. Special products including glass ceramics, optical fibers, photosensitive glasses, etc. Visit to a glass manufacturing plant may also be included.

MAT 431 Sintering Theory and Practice 3 Credits
Science and technology of the sintering of solid-state materials. Driving force and variables. Critical review of the sintering models. Coverage of single phase, multiphase and composite systems. Special sintering techniques such as fast firing, rate controlled sintering, hot pressing and transient second-phase sintering. Sintering of specific ceramic and metal systems.

MAT 442 Inorganic Glasses 3 Credits
Definition, formation and structure of glass; common glass systems; manufacturing processes; optical, mechanical, electrical and dielectric properties; chemical durability; glass fibers and glass ceramics.
Lectures and laboratories. Credit is not given for both MAT 342 and MAT 442.

MAT 443 (CHM 443) Solid-State Chemistry 3 Credits
Crystal structure, diffraction in crystals and on surfaces, bonding and energy spectra in solids, dielectrics, surface states and surface fields in crystals. Must have completed one course in linear algebra and one course in quantum mechanics.

MAT 445 Additive Manufacturing and Powder Metallurgy 3 Credits
Application of powder metallurgy in emerging technologies in the field of Additive Manufacturing (aka 3-D Printing). Metal powder fabrication and characterization methods. Powder processing including powder compaction, theory of compacting, press and die design, sintering, hot consolidation and additive manufacturing. Microstructure and properties of sintered materials and their relationship to processing conditions. Industrial applications. Emerging powder metallurgy technologies. Graduate version of MAT 345 requiring additional assignments. Credit is not given for both MAT 345 and MAT 445.

MAT 455 Materials for Nanotechnology 3 Credits
An introduction to the nanoworld and how we observe the nanoworld through transmission electron microscopy. Other topics include: probing nanosurfaces, carbon as a nanomaterial, fullerences, carbon nanotubes, metal clusters, metal nanoparticle preparation, and directed self-assembly of nanoparticles. Also discussed are the thermal, chemical, electronic, optical, and magnetic properties of metal nanoparticles, nanowires, semiconductor nanoparticles, and inorganic nanoparticles.

MAT 456 Strategies for Nanocharacterization 3 Credits
Lectures describe various nanocharacterization techniques in terms of which technique is best for specific measurements on nanostructures less than 100 nm in extent. Special attention is paid to spatial resolution and detection limits for SEM, TEM, X-ray analysis, diffraction analysis, ion beam techniques, surface techniques, AFM and other SPMs, and light microscopies and spectroscopies.

MAT 459 Thin Film Deposition, Processing, and Characterization 3 Credits
Thin films are at the heart of electronics, optics, medicine, and nanotechnology. Fundamental and applied aspects of thin film deposition, processing, and characterization. Growth methods including physical and chemical deposition techniques. Equipment and hardware for deposition and analysis. Structural, mechanical, electronic, and chemical properties of films. Processing methods and their relationship to specific applications. Graduate version of MAT 359 with extra assignments for graduate students. Credit will not be given for both MAT 359 and MAT 459.
Prerequisites: MAT 332 or MAT 333

MAT 460 Engineering Project 1-6 Credits
In-depth study of a problem in the area of materials engineering or design. The study is to lead to specific conclusions and be embodied in a written report. Intended for candidates for the M.Eng.
Repeat Status: Course may be repeated.

MAT 462 Independent Study 1-4 Credits
An intensive study, with report, of a topic in materials science and engineering which is not treated in other courses. Consent of instructor required.
Repeat Status: Course may be repeated.
MAT 463 Computational Methods in Science and Engineering 3 Credits
Computer simulation of systems at various length and time scales. Atomistic simulation (molecular dynamics and Monte Carlo) methods are presented and applied to models described by simple interatomic potentials. Mesoscale simulation is described in the context of domain growth and, at the continuum scale, finite-difference and finite-element methods are employed to model heat conduction and mass diffusion. Lecture and computer laboratory sessions. Extra assignments provided to graduate students. Credit will not be given for both MAT 363 and MAT 463.

MAT 482 (CHE 482, CHM 482) Mechanical Behaviors of Polymers 3 Credits
A treatment of the mechanical behavior of polymers. Characterization of experimentally observed viscoelastic response of polymeric solids with the aid of mechanical model analogs. Topics include time-temperature superposition, experimental characterization of large deformation and fracture processes, polymer adhesion, and the effects of fillers, plasticizers, moisture and aging on mechanical behavior.

MAT 483 (CHE 483, CHM 483) Emulsion Polymers 3 Credits
Examination of fundamental concepts important in the manufacture, characterization, and application of polymer latexes. Topics to be covered will include colloidal stability, polymerization mechanisms and kinetics, reactor design, characterization of particle surfaces, latex rheology, morphology considerations, polymerization with functional groups, film formation and various application problems.

MAT 485 (CHE 485, CHM 485) Polymer Blends and Composites 3 Credits
Synthesis, morphology, and mechanical behavior of polymer blends and composites. Mechanical blends, block and graft copolymers, interpenetrating polymer networks, polymer impregnated concrete, and fiber and particulate reinforced polymers are emphasized. Must have completed any introductory polymer course or equivalent.

MAT 486 Polymer Nanocomposites 3 Credits
Synthesis, morphology and properties of polymer nanocomposites. Comparisons with traditional particulate composites will be made and models predicting properties will be emphasized. Melt viscosity, mechanical properties, barrier properties and flame retardancy will be discussed. This course is a version of MAT 386 for graduate students, with additional research projects and advanced assignments. Closed to students who have taken MAT 386. Credit is not given for both MAT 386 and MAT 486.

MAT 487 Adhesion and Adhesives Technology 3 Credits
Basics of intermolecular forces, surface science, and mechanics of materials and how these relate to adhesion. Processing and design of adhesive joints. Formulation and behavior of pressure sensitive and structural adhesives. Background in polymers is helpful.

MAT 490 Thesis 1-6 Credits
Repeat Status: Course may be repeated.

MAT 492 (CHE 492, CHM 492) Topics in Polymer Science 1-3 Credits
Intensive study of topics selected from areas of current research interest such as morphology and mechanical behavior, thermodynamics and kinetics of crystallization, new analytical techniques, molecular weight distribution, non-Newtonian flow behavior, second-order transition phenomena, novel polymer structures. Credit above three hours is granted only when different material is covered.

MAT 499 Dissertation 1-15 Credits
Repeat Status: Course may be repeated.