MATERIALS SCIENCE AND ENGINEERING

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Courses in Materials Science and Engineering have the subject code MATSCI. For a complete list of subject codes, see Appendix.

The Department of Materials Science and Engineering is concerned with the relation between the structure and properties of materials, factors that control the internal structure of solids, and processes for altering their structure and properties. The undergraduate program, described under the "School of Engineering" section of this bulletin, provides training for the materials engineer and also preparatory training for graduate work in materials science. Capable students are encouraged to take at least one year of graduate study to extend their course work to obtain a coterminal degree. Coterminal degree programs are encouraged both for undergraduate majors in Materials Science and Engineering and for undergraduate majors in related disciplines. Graduate programs lead to the degrees of Master of Science, Engineer, and Doctor of Philosophy.

FACILITIES

The department is based in the Thomas F. Peterson Engineering Laboratory (Building 550), with extensive facilities in the Jack A. McCullough building and the Gordon and Betty Moore Materials Research Building. These buildings house offices for the chair and most of the faculty, for the administrative and technical staff, and for most graduate students, along with lecture and seminar rooms. Facilities for teaching and research are also available, including equipment for electrical measurements; mechanical testing of bulk and thin film materials; fracture and fatigue of advanced materials; metallography; optical, scanning, transmission electron microscopy, and atomic force microscopy; UHV sputter deposition; vacuum annealing treatments; wet chemistry; and x-ray diffraction. The McCullough/Moore Complex is also the home for the Center for Magnetic Nanotechnology, with corresponding facilities for magnetic measurements. The Rapid Prototyping Laboratory (RPL), housing material deposition and removal stations, is a joint facility with Mechanical Engineering, and is housed next to the Peterson Labs in Building 530. The department maintains two microcomputer clusters for its students, both of which are linked to the Internet.

Depending on the needs of their programs, students and faculty also conduct research in a number of other departments and independent laboratories. Chief among these are the Center for Integrated Systems (CIS), the Geballe Laboratory for Advanced Materials (GLAM), and the Stanford Synchrotron Radiation Laboratory (SSRL).

The Center for Integrated Systems (CIS) is a laboratory joining government and industrially funded research on microelectronic materials, devices, and systems. It houses a 10,000 square foot, class 100 clean room for Si and GaAs integrated circuit fabrication; a large number of electronic test, materials analysis, and computer facilities; and office space for faculty, staff, and students. In addition, CIS provides startup research funds and maintains a "Fellow-Mentor" program with industry.

For information on GLAM and SSRL, see the "Geballe Laboratory for Advanced Materials" and "Stanford Synchrotron Radiation Laboratory" sections of this bulletin.

UNDERGRADUATE PROGRAMS

BACHELOR OF SCIENCE

The undergraduate program provides training in solid state fundamentals and materials engineering. Students desiring to specialize in this field during their undergraduate period may do so by following the curriculum outlined in the "School of Engineering" section of this bulletin as well as the *School of Engineering Undergraduate Handbook*. The University's basic requirements for the bachelor's degree are discussed in the "Undergraduate Degrees" section of this bulletin. Electives are available so that students with broad interests can combine materials science and engineering with work in another science or engineering department.

For information about minor, see the "School of Engineering" section of this bulletin.

COTERMINAL B.S./M.S. PROGRAM

Stanford undergraduates who wish to continue their studies for the Master of Science degree in the coterminal program may apply for admission after they have earned 120 units toward graduation (UTG) as shown on the undergraduate unofficial transcript; applicants must submit their application no later than the quarter prior to the expected completion of their undergraduate degree. The application must give evidence that the student possesses the potential for strong academic performance at the graduate level. Scores from the Graduate Record Exam (GRE) General Test must be reported before action can be taken on an application. Materials science is a highly integrated and interdisciplinary subject, and so applications from students of any engineering or science undergraduate major are encouraged. Information forms pertaining to the coterminal program may be obtained from the department's student services manager, Room 551F, or from the Degree Progress in the Office of the University Registrar, 630 Serra Street, Suite 120.

For University coterminal degree program rules and University application forms, see http://registrar.stanford.edu/shared/publications.htm#Coterm.

GRADUATE PROGRAMS

Graduate students can specialize in any of the areas of materials science and engineering.

MASTER OF SCIENCE

The University's basic requirements for the M.S. degree are discussed in the "Graduate Degrees" section of this bulletin. The following are specific departmental requirements.

The Department of Materials Science and Engineering requires a minimum of 45 units for a master's degree to be taken in residence at Stanford. Master's Program Proposal forms should be filled out, signed by the student's academic adviser, and submitted to the department's student services manager by the end of the student's first quarter of study. Final changes to the master's program must be submitted no later than one academic quarter prior to degree conferral. Stanford Materials Science undergraduates who are pursuing or who plan to pursue a coterminal M.S. degree may have more flexibility in their programs and should consult with their academic advisers regarding appropriate core course and elective choices.

Degree requirements are as follows:

1. A minimum of 30 units of Materials Science course work, including core and lab courses specified below, taken for a letter grade. Research units, one-unit seminars, and courses in other departments (i.e., where students cannot enroll in a class with a MATSCI subject code) cannot be counted for this requirement.
2. Three core courses: 203; 204; 207.
3. Lab courses: MATSCI 171, 172, 173. *Note:* students who have had equivalent lab courses at other universities, equivalent practical experience, a materials related degree or background, or passed the Ph.D. qualifying exam, are expected to file a petition with the department's student services manager to have this requirement waived and to substitute other appropriate technical courses for the lab units.
4. 15 units of approved course electives that result in a technically coherent program. Of the 15 units of elective courses:
   a) 12 of the 15 units must be taken for a letter grade (except for those submitting an M.S. report).
   b) a maximum of 3 units may be seminars.
   c) if writing a master's research report, a minimum of 6 and a maximum of 15 units of Materials Science research units (MATSCI 200) may be counted. M.S. research units may only be counted if writing an M.S. research report.
   d) a maximum of 3 units may be undergraduate units (offered at Stanford University).
   e) a maximum of 5 units may be used for a foreign language course (not including any remedial English courses or courses in the student's native language if other than English).
   f) the combination of seminar, undergraduate, and language units may not exceed 6 units total.
   g) the combination of research, seminar, undergraduate, and language units may not exceed 15 units total.
   h) activity units may not be counted toward a graduate degree.
5. A minimum grade point average (GPA) of 2.75 for degree course work taken at Stanford.

All proposed degree programs are subject to approval by the department's student services manager and the Academic Degree Committee, which has responsibility for assuring that each proposal is a technically coherent program.

MASTER'S RESEARCH REPORT

Students wishing to take this option must include 6-15 Materials Science research units on their program proposal and the name of the faculty member who will be supervising the research. Students using 15 units of research toward the degree must participate in a more complex and demanding research project than those using fewer units.

The report must be approved by two faculty members. One faculty member is the student's research adviser. The other faculty member must be approved by the department's student services manager. Three copies of the report (one copy for each approving faculty member and one for the department file), in final form and signed by two faculty members, must be submitted to the department's student services manager one week before final examinations of the final quarter of the program. The report is not an official University thesis but rather is intended to demonstrate to department faculty an ability to conduct and report directed research. Refer to the *Materials Science and Engineering Student Handbook* for further clarification concerning this report.

In cases where students decide to pursue research after the initial program submission deadline, they should submit a revised M.S. Program Proposal at least two quarters before the degree is granted. The total combined units of Materials Science research units, seminars, language courses, and undergraduate courses cannot exceed 15. If a master's research report is not to be submitted, units of MATSCI 200 cannot be applied to the department's requirement of 45 units for the master's degree.

HONORS COOPERATIVE PROGRAM

Some of the department's graduate students participate in the Honors Cooperative Program (HCP), which makes it possible for academically qualified engineers and scientists in industry to be part-time graduate students in Materials Science while continuing professional employment. Prospective HCP students follow the same admissions process and must meet the same admissions requirements as full-time graduate students. For information regarding the Honors Cooperative Program, see the "School of Engineering" section of this bulletin.

PETITION PROCESS FOR TRANSFER FROM M.S. TO PH.D. DEGREE PROGRAM

Students admitted to the graduate program are admitted specifically into either the M.S. or the Ph.D. program. A student admitted to the M.S. program should not assume admission to the Ph.D. program. Admission to the Ph.D. program is required for the student to be eligible to work towards the Ph.D. degree.

A student in the M.S. program may petition to be admitted to the Ph.D. program by filing an M.S. to Ph.D. Transfer Petition. This petition must be accompanied by a one-page statement of purpose stating the reasons why the student wishes to transfer to the Ph.D. program, an updated transcript, and two letters of recommendation from members of the Stanford faculty, including one from the student's prospective adviser and at least one from a Materials Science faculty member belonging to the Academic Council. The M.S. to Ph.D. Transfer Petition is due to the student services manager by the end of the second week of Spring Quarter during the student's first year in the M.S. program. Only students enrolled in the 200 series core course sequence are eligible to petition, and a grade point average (GPA) of 3.25 or better in the core courses is required.

Transferring to the Ph.D. program is a competitive process and only fully qualified M.S. students are admitted. Faculty consider the student's original application to the graduate program as well as the material provided with the transfer petition.

ENGINEER

The University's basic requirements for the degree of Engineer are outlined in the "Graduate Degrees" section of this bulletin.

A student wishing to enter the Engineer program must have completed the requirements of the M.S. in Materials Science and Engineering, and must file a petition requesting admission to the program, stating the type of research to be done and the proposed supervising professor. Once approved, the Application for Candidacy must be submitted to the department's student services manager by the end of the second quarter in the Engineer program. Final changes in the Application for Candidacy form must be submitted no later than one academic quarter prior to degree conferral.

The 90-unit program must include 9 units of graduate courses in Materials Science with a MATSCI subject code (exclusive of research units, seminars, colloquia, and MATSCI 400, Participation in Teaching) beyond the requirements for the M.S. degree, and additional research or other units to meet the 90-unit University minimum requirement. A grade point average (GPA) of 3.0 must be maintained for all degree course work taken at Stanford.

Completion of an acceptable thesis is required. The Engineer thesis must be approved by two Academic Council faculty members, one of whom must be a member of the department, and submitted in triplicate.

DOCTOR OF PHILOSOPHY

The University's basic requirements for the Ph.D. degree are outlined in the "Graduate Degrees" section of this bulletin.

Degree requirements are as follows:

1. Submit a Ph.D. program consisting of at least 135 units,† which contains a minimum of 57 technical course units. Of these 57 units:
   a) at least 54 of the 57 units must be for a letter grade
   b) 33 units must be taken as Materials Science courses with a MATSCI subject code for a letter grade
   c) students must take six core courses for a letter grade*

1) 203, 204, and 207 are required of first-year students
2) students must take three additional core courses in their first year from the following: 202, 205, 206, 208, 209, 210.

d) a minimum of 12 units of 300-level Materials Science courses (not including MATSCI 300, Ph.D. Research, or MATSCI 400, Participation in Materials Science Teaching)
e) a minimum of 12 units of courses taken from one of the following lists of advanced specialty courses (see below). Some or all of these courses can be the same as the courses used to meet the requirement of 12 units of 300-level courses; however, the units may not be counted twice toward the 57 technical or 135 total degree units.
f) elective technical courses to bring the total units up to 57
g) the remaining units beyond the 57 units of technical course work may consist of Ph.D. research, seminars, and teaching experience.

2. First-year Ph.D. students are required to take the Materials Science Colloquium, MATSCI 230, each quarter of their first year (not counted as technical course units).
3. Ph.D. students are required to obtain an M.S. degree in Materials Science normally by the end of their second year. Paperwork must be submitted prior to taking the qualifying examination. Courses taken for the 57 technical units of Ph.D. work may count to meet the M.S. degree requirements.
4. A departmental oral qualifying examination must be passed by the end of January of their second year. A grade point average (GPA) of 3.25 from the six core classes taken is required for admission to the Ph.D. qualifying exam. Students who have passed the departmental oral examination are required to complete the Application for Candidacy for the Ph.D. Degree by the end of the quarter in which they pass the exam. Final changes in the Application for Candidacy form must be submitted no later than one academic quarter prior to degree conferral.
5. Maintain a GPA of 3.0 in all degree courses taken at Stanford.
6. Present the result of the dissertation at the University oral examination.

* Students may, if they have sufficient background, petition out of some of the required core courses. To successfully petition, students must have prior permission from their academic adviser, and also permission from the instructor of the particular core course. That instructor provides an oral or written examination that the petitioning student must pass.

† At least 90 units must be taken in residence at Stanford. Students entering with an M.S. degree in Materials Science from another university may request to transfer up to 45 units of equivalent work toward the total of 135 required units.

ADVANCED SPECIALTY COURSES

1. Biomaterials: APPPHYS 292; BIOPHYS 228; CHEMENG 260, 310, 355, 444, 452; ME 284A,B, 381, 385, 386, 457
2. Electronic Materials Processing: EE 212, 216, 217, 311, 316, 410; MATSCI 312, 313, 330
3. Materials Characterization: APPPHYS 216, 218; CHEMENG 345; EE 329; MATSCI 320, 321, 322, 323, 324, 325
4. Mechanical Behavior of Solids: AA 252, 256; MATSCI 251, 270, 352, 353, 358; ME 335A,B,C, 338, 340, 340B, 345
5. Physics of Solids and Computation: APPPHYS 218, 272, 273; CHEMENG 444; EE 222, 223, 228, 327, 328, 329, 335; MATSCI 330, 343, 347; ME 344A,B, 444B
6. Soft Materials: CHEMENG 260, 310, 460; MATSCI 343; ME 455.

PH.D. MINOR

The University's basic requirements for the Ph.D. minor are outlined in the "Graduate Degrees" section of this bulletin. A minor requires 20 units of graduate work of quality and depth to be approved by the Advanced Degree Committee of the department. Individual programs must be submitted to the Student Services Manager at least one quarter prior to degree conferral and approved as are other academic plans.

COURSES

PRIMARILY FOR UNDERGRADUATES

MATSCI 70N. Building the Future: Invention and Innovation with Engineering Materials—Stanford Introductory Seminar. Preference to freshmen. The technological importance of materials in human civilization is captured in historical names such as the Stone, Bronze, and Iron Ages. The present Information Age could rightly be called the Silicon Age. The pivotal roles of materials in the development of new technologies. Quantitative problem sets, field trips, and formal presentations of small-group projects. GER:DB-EngrAppSci, WRITE-2

5 units, Spr (Bravman, J)

MATSCI 100. Undergraduate Independent Study—Independent study in materials science under supervision of a faculty member.

1-3 units, Aut, Win, Spr, Sum (Staff)

MATSCI 150. Undergraduate Research—Participation in a research project.

3-6 units, Aut, Win, Spr, Sum (Staff)

MATSCI 151. Microstructure and Mechanical Properties—(Same as 251.) Primarily for students without a materials background. Mechanical properties and their dependence on microstructure in a range of engineering materials. Elementary deformation and fracture concepts, strengthening and toughening strategies in metals and ceramics. Topics: dislocation theory, mechanisms of hardening and toughening, fracture, fatigue, and high-temperature creep. Prerequisite: ENGR 50 or equivalent. GER: DB-EngrAppSci

4 units, Aut (Dauskardt, R)

MATSCI 152. Electronic Materials Engineering—Materials science and engineering for electronic device applications. Kinetic molecular theory and thermally activated processes; band structure and electrical conductivity of metals and semiconductors; intrinsic and extrinsic semiconductors; diffusion; elementary p-n junction theory; operating principles of metal-oxide-semiconductor field effect transistors; introduction to crystal growth; oxidation kinetics; ion implantation; thermodynamics and kinetics of chemical vapor deposition; survey of physical vapor deposition methods, etching, and photolithography. GER:DB-EngrAppSci

4 units, Spr (Staff)

MATSCI 153. Nanostructure and Characterization—The structure of materials at the nanoscale is in most cases the same crystalline form as the natural phase. Structures of materials such as semiconductors, ceramics, metals, and nanotubes; classification of these materials according to the principles of crystallography. Primary methods of structural characterization, X-ray diffraction, and electron microscopy and their applications to study such nanostructures. GER:DB-EngrAppSci

4 units, Win (Sinclair, R)

MATSCI 154. Solid State Thermodynamics—The principles of thermodynamics and relationships between thermodynamic variables. Equilibrium in thermodynamic systems. Thermodynamics of multicomponent systems. Prerequisite: physical chemistry or introductory thermodynamics. GER:DB-EngrAppSci

4 units, Aut (Barnett, D)

MATSCI 155. Nanomaterials Synthesis—The science of synthesis of nanometer scale materials. Examples including solution phase synthesis of nanoparticles, the vapor-liquid-solid approach to growing nanowires, formation of mesoporous materials from block-copolymer solutions, and formation of photonic crystals. Relationship of the synthesis phenomena to the materials science driving forces and kinetic mechanisms. Materials science concepts including capillarity, Gibbs free energy, phase diagrams, and driving forces. Prerequisite: ENGR 50, and MATSCI 154 or CHEMENG 110. GER:DB-EngrAppSci

4 units, Spr (Clemens, B)

MATSCI 159Q. Japanese Companies and Japanese Society—(Same as ENGR 159Q.) Stanford Introductory Seminar. Preference to sophomores. The structure of a Japanese company from the point of view of Japanese society. Visiting researchers from Japanese companies give presentations on their research enterprise. The Japanese research ethic. The home campus equivalent of a Kyoto SCTI course. GER:DB-SocSci
3 units, Spr (Sinclair, R)

MATSCI 160. Nanomaterials Laboratory—Preference to sophomores and juniors. Hands-on approach to synthesis and characterization of nanoscale materials. How to make, pattern, and analyze the latest nanotech materials, including nanoparticles, nanowires, and carbon nanotubes. Techniques such as soft lithography, self-assembly, and surface functionalization. The VLS mechanism of nanowire growth, nanoparticle size control, self-assembly mechanisms, and surface energy considerations. Laboratory projects. Enrollment limited to 24. GER:DB-EngrAppSci
4 units, Spr (Melosh, N)

MATSCI 161. Nanocharacterization Laboratory—(Same as 171.) The development of standard lab procedures for materials scientists emphasizing microscopy, metallography, and technical writing. Techniques: optical, scanning-electron, atomic-force microscopy; and metallographic specimen preparation. The relationships among microscopic observation, material properties, and processing. Prerequisite: ENGR 50 or equivalent. GER:DB-EngrAppSci, WIM
4 units, Win (Staff)

MATSCI 162. X-Ray Diffraction Laboratory—(Same as 172.) Introduction to x-ray diffraction for microstructural analysis of materials, emphasizing powder and single-crystal techniques. Diffraction from thin films, thin-film multilayers, amorphorous materials, strain measurements, orientation measurements, and electron diffraction. Prerequisite: 193/203. GER:DB-EngrAppSci
4 units, Win (Vailionis, A)

MATSCI 163. Mechanical Behavior Laboratory—(Same as 173.) Experimental techniques for the study of the mechanical behavior of engineering materials in bulk and thin film form, including tension testing, nanoindentation, and wafer curvature stress analysis. Metallic and polymeric systems will be studied. Prerequisites: 198/208, 151/251, ME 80 or equivalent. GER:DB-EngrAppSci
4 units, Aut (Staff)

MATSCI 164. Electronic and Photonic Materials and Devices Laboratory—Lab course. Current electronic and photonic materials and devices. Device physics and micro-fabrication techniques. Students design, fabricate, and perform physical characterization on the devices they have fabricated. Established techniques and materials such as photolithography, metal evaporation, and Si technology; and novel ones such as soft lithography and organic semiconductors.
4 units, not given this year (Salleo, A)

MATSCI 170. Materials Selection in Design—(For undergraduates; see 270.) GER:DB-EngrAppSci
4 units, not given this year (Prinz, F)

MATSCI 171. Nanocharacterization Laboratory—(For graduate students; see 161.)
3units, Win (Staff)

MATSCI 172. X-Ray Diffraction Laboratory—(For graduate students; see 162.)
3 units, Win (Vailionis, A)

MATSCI 173. Mechanical Behavior Laboratory—(For graduate students; see 163.)
3 units, Aut (Staff)

MATSCI 190. Organic Materials—(For undergraduates; see 210.) GER:DB-EngrAppSci
4 units, Spr (Heilshorn, S)

MATSCI 192. Materials Chemistry—(For undergraduates; see 202.) GER: DB-NatSci, DB-EngrAppSci
4 units, Aut (Cui, Y)

MATSCI 193. Atomic Arrangements in Solids—(For undergraduates; see 203.) GER:DB-EngrAppSci
4 units, Aut (Sinclair, R)

MATSCI 194. Phase Equilibria—(For undergraduates; see 204.) GER: DB-EngrAppSci
4 units, Win (Salleo, A)

MATSCI 195. Waves and Diffraction in Solids—(For undergraduates; see 205.) GER:DB-EngrAppSci
4 units, Win (Clemens, B)

MATSCI 196. Imperfections in Crystalline Solids—(For undergraduates; see 206.) GER:DB-EngrAppSci
4 units, Win (Nix, W)

MATSCI 197. Rate Processes in Materials—(For undergraduates; see 207.) GER:DB-EngrAppSci
4 units, Spr (McIntyre, P)

MATSCI 198. Mechanical Properties of Materials—(For undergraduates; see 208.) GER:DB-EngrAppSci
4 units, Spr (Dauskardt, R)

MATSCI 199. Electronic and Optical Properties of Solids—(For undergraduates; see 209.) GER:DB-EngrAppSci
4 units, Spr (Brongersma, M)

PRIMARILY FOR GRADUATE STUDENTS

MATSCI 200. Master's Research—Participation in a research project.
1-15 units, Aut, Win, Spr, Sum (Staff)

MATSCI 202. Materials Chemistry—(Same as 192.) Chemical principles of materials formed by chemical bonds and intermolecular and surface forces. Crystal structure and bonding; synthesis and characterization of bulk crystals; nanostructures; electronic structures and properties with a comparison between bulk and nano materials; intermolecular and surface forces for self-assembly including electrostatic, van der Waals force, hydrogen bond, hydrophobicity, solvation, entropic force, and DLVO theory; and self-assembled materials. Prerequisite: undergraduate physical chemistry or equivalent.
3 units, Aut (Cui, Y)

MATSCI 203. Atomic Arrangements in Solids—(Same as 193.) Atomic arrangements in perfect and imperfect crystalline solids, especially important metals, ceramics, and semiconductors. Elements of formal crystallography, including development of point groups and space groups.
3 units, Aut (Sinclair, R)

MATSCI 204. Phase Equilibria—(Same as 194.) The principles of heterogeneous equilibria and their application to phase diagrams. Thermodynamics of solutions; chemical reactions; non-stoichiometry in compounds; first order phase transitions and metastability; higher order transitions; and thermodynamics of surfaces, elastic solids, dielectrics and magnetic solids. Prerequisite: 192/202 or consent of instructor.
3 units, Win (Salleo, A)

MATSCI 205. Waves and Diffraction in Solids—(Same as 195.) The elementary principals of x-ray, vibrational, and electron waves in solids. Basic wave behavior including Fourier analysis, interference, diffraction, and polarization. Examples of wave systems, including electromagnetic waves from Maxwell's equations. Diffracted intensity in reciprocal space and experimental techniques such as electron and x-ray diffraction. Lattice vibrations in solids, including vibrational modes, dispersion relationship, density of states, and thermal properties. Free electron model. Basic quantum mechanics and statistical mechanics including Fermi-Dirac and Bose-Einstein statistics. Prerequisite: 193/203 or consent of instructor.
3 units, Win (Clemens, B)

MATSCI 206. Imperfections in Crystalline Solids—(Same as 196.) The relation of lattice defects to the physical and mechanical properties of crystalline solids. Introduction to point imperfections and their relationship to transport properties in metallic, covalent, and ionic crystals. Geometric, crystallographic, elastic, and energetic properties of dislocations. Relations between dislocations and the mechanical properties of crystals. The structure and properties of interfaces in solids. Prerequisite: 193/203.
3 units, Win (Nix, W)

MATSCI 207. Rate Processes in Materials—(Same as 197.) Diffusion and phase transformations in solids. Diffusion topics: Fick's laws, atomic theory of diffusion, and diffusion in alloys. Phase transformation topics: nucleation, growth, diffusional transformations, spinodal decomposition, and interface phenomena. Material builds on the mathematical, thermodynamic, and statistical mechanical foundations in the prerequisites. Prerequisites: 194/204.
3 units, Spr (McIntyre, P)

MATSCI 208. Mechanical Properties of Materials—(Same as 198.) Introduction to the mechanical behavior of solids, emphasizing the relationships between microstructure and mechanical properties. Elastic, anelastic, and plastic properties of materials. The relations between stress, strain, strain rate, and temperature for plastically deformable solids. Application of dislocation theory to strengthening mechanisms in crystalline solids. The phenomena of creep, fracture, and fatigue and their controlling mechanisms. Prerequisites: 193/203.
3 units, Spr (Dauskardt, R)

MATSCI 209. Electronic and Optical Properties of Solids—(Same as 199.) The concepts of electronic energy bands and transports applied to metals, semiconductors, and insulators. The behavior of electronic and optical devices including pn junctions, MOS-capacitors, MOSFETs, optical waveguides, quantum-well lasers, light amplifiers, and metallo-dielectric light guides. Emphasis is on relationships between structure and physical properties. Elementary quantum and statistical mechanics concepts are used. Prerequisite: 195/205 or equivalent.
3 units, Spr (Brongersma, M)

MATSCI 210. Organic Materials—(Same as 190.) Unique physical and chemical properties of organic materials and their uses.The relationship between structure and physical properties, and techniques to determine chemical structure and molecular ordering. Examples include liquid crystals, dendrimers, carbon nanotubes, hydrogels, and biopolymers such as lipids, protein, and DNA.
3 units, Spr (Heilshorn, S)

MATSCI 230. Materials Science Colloquium—May be repeated for credit.
1 unit, Aut, Win, Spr (Staff)

MATSCI 251. Microstructure and Mechanical Properties—(For graduate students; see 151.)
3 units, Aut (Dauskardt, R)

MATSCI 270. Materials Selection in Design—(Same as 170.) Methods to select materials for engineering applications, emphasizing structural and thermal properties. Fundamentals of the interrelation between materials parameters. Strategies for optimal selection subject to performance, processing, and manufacturing constraints. Materials selection with and without shape considerations. Use of materials databases. Design case studies. Material synthesis methodologies. Prerequisite: ENGR 14 and 50 or ME 111.
3 units, not given this year (Prinz, F)

MATSCI 299. Practical Training—Educational opportunities in high-technology research and development labs in industry. Qualified graduate students engage in internship work and integrate that work into their academic program. Following the internship, students complete a research report outlining their work activity, problems investigated, key results, and any follow-on projects they expect to perform. Student is responsible for arranging own employment. See department student services manager before enrolling.
3 units, Aut, Win, Spr, Sum (Staff)

MATSCI 300. Ph.D. Research—Participation in a research project.
1-15 units, Aut, Win, Spr, Sum (Staff)

MATSCI 302. Solar Cells—Theory of conventional pn junction and excitonic solar cells. Design, fabrication, and characterization of crystalline silicon, amorphous silicon, CdTe, CIGS, and tandem and organic solar cells. Emerging solar cell concepts such as intermediate band gap and bioinspired solar cells. Emphasis is on the materials science aspects of solar cells research. Module design and economic hurdles that must be overcome for solar cell technology to generate a significant fraction of the world's electricity. Group project to explore one solar cell approach in depth.
3 units, Aut (McGehee, M)

MATSCI 311. Lasers in Materials Processing—Principles of laser operation. Optically and electrically pumped lasers. Materials for solid-state lasers. Fundamentals of laser/materials interactions. Applications in thin film technology and microfabrication; laser annealing of defects and crystallization of amorphous films. Laser-induced shock waves. Extreme non-equilibrium laser processing; ultra-fast (femtosecond) lasers and their novel uses; micro- and nanofabrication of fluidic and photonic devices; intracellular nano-surgery.
3 units, Spr (Salleo, A)

MATSCI 312. New Methods in Thin Film Synthesis—Materials base for engineering new classes of coatings and devices. Techniques to grow thin films at atomic scale and to fabricate multilayers/superlattices at nanoscale. Vacuum growth techniques including evaporation, molecular beam epitaxy (MBE), sputtering, ion beam assisted deposition, laser ablation, chemical vapor deposition (CVD), and electroplating. Future direction of material synthesis such as nanocluster deposition and nanoparticles self-assembly. Relationships between deposition parameters and film properties. Applications of thin film synthesis in microelectronics, nanotechnology, and biology. SITN/SCPD televised.
3 units, Aut (Wang, S)

MATSCI 316. Nanoscale Science, Engineering, and Technology—Sample application areas: renewable energy including nanoscaled photovoltaic cells, hydrogen storage, fuel cells, and nanoelectronics. Nanofabrication techniques including: self-assembly of amphiphilic molecules, block copolymers, organic-inorganic mesostructures, colloidal crystals, organic monolayers, proteins, DNA and abalone shells; biologically inspired growth of materials; photolithography, electron beam lithography, and scanning probe lithography; and synthesis of carbon nanotubes, nanowire, and nanocrystals. Other nanotechnology topics may be explored through a group project. SITN/SCPD televised.
3 units, Win (Cui, Y; McGehee, M)

MATSCI 320. Nanocharacterization of Materials—Current methods of directly examining the microstructure of materials. Topics: optical microscopy, scanning electron and focused ion beam microscopy, field ion microscopy, transmission electron microscopy, scanning probe microscopy, and microanalytical surface science methods. Emphasis is on the electron-optical techniques. Recommended: 193/203.
3 units, alternate years, not given this year (Sinclair, R)

MATSCI 321. Transmission Electron Microscopy—Image formation and interpretation. The contrast phenomena associated with perfect and imperfect crystals from a physical point of view and from a formal treatment of electron diffraction theory. The importance of electron diffraction to systematic analysis and recent imaging developments. Recommended: 193/203, 195/205, or equivalent.
3 units, Win (Sinclair, R), alternate years, not given next year

MATSCI 322. Transmission Electron Microscopy Laboratory—Experimental application of electron microscopy to typical materials science studies. Topics include microscope operation and alignment, diffraction modes and analysis, bright-field/dark-field analysis of defects, high resolution imaging, and analytical techniques for compositional analysis (EDAX). Enrollment limited to 12. Prerequisites: 321, consent of instructor.
3 units, Spr (Marshall, A)

MATSCI 323. Thin Film and Interface Microanalysis—The science and technology of microanalytical techniques, including Auger electron spectroscopy (AES), Rutherford backscattering spectroscopy (RBS), secondary ion mass spectroscopy (SIMS), ion scattering spectroscopy (ISS), and x-ray photoelectron spectroscopy (XPS or ESCA). Generic processes such as sputtering and high-vacuum generation. Prerequisite: some prior exposure to atomic and electronic structure of solids. SITN/SCPD televised.
3 units, Aut (Koster, G)

MATSCI 324. Topics in Thin Film Microcharacterization—Case study characterizing materials, defining problems in characterizing surfaces or thin films, analyzing samples, and reporting results. Students propose problems, and operate electron, ion, and x-ray probe instruments. Methodology for approaching characterization problems; experience in interpreting and presenting experimental results. Emphasis is on application of advanced measurement methods to practical problems, and capabilities and limitations of modern techniques. Topics: choosing techniques, analytical pitfalls, quantitative analysis, effects of noise and other uncertainties on analytical precision. Enrollment limited. Prerequisite: 323 or consent of instructor.
3 units, not given this year

MATSCI 325. X-Ray Diffraction—Diffraction theory and its relationship to structural determination in solids. Focus is on applications of x-rays; concepts can be applied to neutron and electron diffraction. Topics: Fourier analysis, kinematic theory, Patterson functions, diffraction from layered and amorphous materials, single crystal diffraction, dynamic theory, defect determination, surface diffraction, techniques for data analysis, and determination of particle size and strain. Prerequisites: 193/203, 195/205.
3 units, Aut (Clemens, B) alternate years, not given next year

MATSCI 343. Organic Semiconductors for Electronics and Photonics—The science of organic semiconductors and their use in electronic and photonic devices. Topics: methods for fabricating thin films and devices; relationship between chemical structure and molecular packing on properties such as band gap, charge carrier mobility and luminescence efficiency; doping; field-effect transistors; light-emitting diodes; lasers; biosensors; photodetectors and photovoltaic cells. SITN/SCPD televised.
3 units, Spr (McGehee, M)

MATSCI 346. Nanophotonics—(Same as EE 336.) Recent developments in micro- and nanophotonic materials and devices. Concepts of photonic crystals. Integrated photonic circuits. Photonic crystal fibers. Superprism effects. Optical properties of metallic nanostructures. Sub-wavelength phenomena and plasmonic excitations. Meta-materials. SITN/SCPD televised. Prerequisite: electromagnetic theory at the level of EE 142.
3 units, Win (Fan, S; Brongersma, M)

MATSCI 347. Introduction to Magnetism and Magnetic Nanostructures—Atomic origins of magnetic moments, magnetic exchange and ferromagnetism, types of magnetic order, magnetic anisotropy, domains, domain walls, hysteresis loops, hard and soft magnetic materials, demagnetization factors, and applications of magnetic materials, especially magnetic nanostructures and nanotechnology. Tools include finite-element and micromagnetic modeling. Design topics include electromagnet and permanent magnet, electronic article surveillance, magnetic inductors, bio-magnetic sensors, and magnetic drug delivery. Design projects, team work, and computer-aided design. Prerequisites: PHYSICS 29 and 43, or college-level electricity and magnetism.
3 units, Spr (Wang, S; White, R)

MATSCI 352. Stress Analysis in Thin Films and Layered Composite Media—Introduction to methods of stress analysis of layered dissimilar media, including thin films deposited on substrates, composite laminates, and stratified anisotropic elastic materials based on techniques pioneered by Stroh. Stress states generated by thermal and elastic mismatch and local stress concentrations at interfacial cracks or corners, with applications to integrated circuit devices, aircraft materials, and geophysical media. Prerequisites: introductory course on the strength of materials or the theory of elasticity; familiarity with matrix algebra.
3 units, not given this year (Barnett, D)

MATSCI 353. Mechanical Properties of Thin Films—The mechanical properties of thin films on substrates. The mechanics of thin films and of the atomic processes which cause stresses to develop during thin film growth. Experimental techniques for studying stresses in and mechanical properties of thin films. Elastic, plastic, and diffusional deformation of thin films on substrates as a function of temperature and microstructure. Effects of deformation and fracture on the processing of thin film materials. Prerequisite: 198/208.
3 units, Spr (Nix, W) alternate years, not given next year

MATSCI 358. Fracture and Fatigue of Engineering Materials—Linear-elastic and elastic-plastic fracture mechanics from a materials science perspective, emphasizing microstructure and the micromechanisms of fracture. Plane strain fracture toughness and resistance curve behavior. Mechanisms of failure associated with cleavage and ductile fracture in metallic materials and brittle fracture of ceramics and their composites. Fracture mechanics approaches to toughening and subcritical crack-growth processes, with examples and applications in advanced materials including cyclic fatigue and high-temperature creep of metals and ceramics. SITN/SCPD televised. Prerequisite: 151/251, 198/208, or equivalent.
3 units, Win (Dauskardt, R)

MATSCI 359. Crystalline Anisotropy—(Same as ME 336.) Matrix and tensor analysis with applications to the effects of crystal symmetry on elastic deformation, thermal expansion, diffusion, piezoelectricity, magnetism, thermodynamics, and optical properties of solids, on the level of J. F. Nye's *Physical Properties of Crystals*. Homework sets use Mathematica.
3 units, Win (Barnett, D)

MATSCI 380. Molecular Biomaterials—For students with engineering backgrounds interested in the interface between biology and materials science The characteristics of natural and man-made biomaterials from a molecular perspective. Why molecules with particular structures and properties are used for drug delivery, cell scaffolding, and surface passivation. Goal is to exploit these characteristics to create new materials and devices. Engineering strategies to interface biological species with inorganic, man-made devices.
3 units, not given this year (Melosh, N)

MATSCI 381. Biomaterials in Regenerative Medicine—Materials design and selection for regenerative medicine. How materials interact with cells through their micro- and nanostructure, mechanical properties, degradation characteristics, surface chemistry, and biochemistry. Examples include novel materials for drug and gene delivery, materials for stem cell proliferation and differentiation, and tissue engineering scaffolds.
3 units, not given this year (Heilshorn, S)

MATSCI 399. Graduate Independent Study—Under supervision of a faculty member.
1-10 units, Aut, Win, Spr, Sum (Staff)

MATSCI 400. Participation in Materials Science Teaching—May be repeated for credit.
1-3 units, Aut, Win, Spr (Staff)

MATSCI 405. Seminar in Applications of Transmission Electron Microscopy—May be repeated for credit.
1 unit, Aut, Win, Spr (Sinclair, R)

COGNATE COURSES

See respective department listings for course descriptions and General Education Requirements (GER) information. See degree requirements above or the program's student services office for applicability of these courses to a major or minor program.

AA 252. Techniques of Failure Analysis
3 units, Spr (Murray, S)

AA 256. Mechanics of Composites
3 units, Win (Chang, F)

APPPHYS 218. X-Ray and Neutron Scattering in the 21st Century
3 units, alternate years, not given this year

APPPHYS 270. Magnetism and Long Range Order in Solids
3 units, Aut (Fisher, I)

APPPHYS 272/273. Solid State Physics
3 units, **272:** *Win,* **273:** *Spr (Laughlin, R)*

CHEMENG 444. Quantum Simulations of Molecules and Materials
3 units, Win (Musgrave, C)

CHEMENG 460. Polymer Surfaces and Interfaces
3 units, Win (Frank, C)

EE 212. Integrated Circuit Fabrication Processes
3 units, Aut (Plummer, J)

EE 216. Principles and Models of Semiconductor Devices
3 units, Aut (Harris, J), Win (Saraswat, K; Pease, R)

EE 228. Basic Physics for Solid State Electronics
3 units, Aut (Peumans, P)

EE 311. Advanced Integrated Circuit Fabrication Processes
3 units, Spr (Staff)

EE 312. Micromachined Sensors and Actuators
3 units, Win (KovacPs, G)

EE 316. Advanced VLSI Devices
3 units, Win (Wong, P)

EE 327. Properties of Semiconductor Materials
3 units, Spr (Harris, J), alternate years, not given next year

EE 328. Physics of Advanced Semiconductor Devices
3 units, alternate years, not given this year

EE 329. The Electronic Structure of Surfaces and Interfaces
3 units, Aut (Pianetta, P)

EE 335. Introduction to Information Storage Systems
3 units, Win (Wang, S)

EE 410. Integrated Circuit Fabrication Laboratory
3-4 units, Win (Saraswat, K)

ENGR 31. Chemical Principles with Application to Nanoscale Science and Technology
4 units, Aut (McIntyre, P)

ENGR 50. Introduction to Materials Science, Nanotechnology Emphasis
4 units, Win (Melosh, N); Spring (Sinclair, R)

ENGR 50M. Introduction to Materials Science, Biomaterials Emphasis
4 units, Aut (Heilshorn, S)

ME 329. Physical Solid Mechanics
3 units, alternate years, not given this year

ME 340. Elasticity in Microscopic Structures
3 units, Spr (Cai, W)

ME 344A. Computational Nanotechnolgy
3 units, not given this year

ME 344B. Nanomaterials Modeling
3 units, not given this year

ME 345. Fatigue Design and Analysis
3 units, Win (Nelson, D)