Materials Science and Engineering

Courses offered by the Department of Materials Science and Engineering are listed under the subject code MATSCI on the *Stanford Bulletin's* ExploreCourses (http://explorecourses.stanford.edu/browse) web site.

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, particularly at the nanoscale.

Mission of the Undergraduate Program in Materials Science and Engineering

The mission of the undergraduate program in Materials Science and Engineering is to provide students with a strong foundation in materials science and engineering with emphasis on the fundamental scientific and engineering principles which underlie the knowledge and implementation of material structure, processing, properties, and performance of all classes of materials used in engineering systems. Courses in the program develop students' knowledge of modern materials science and engineering, teach them to apply this knowledge analytically to create effective and novel solutions to practical problems, and develop their communication skills and ability to work collaboratively. The program prepares students for careers in industry and for further study in graduate school.

The B.S. in Materials Science and Engineering provides training for the materials engineer and also preparatory training for graduate work in materials science. Capable undergraduates are encouraged to take at least one year of graduate study to extend their course work through the coterminal degree program which leads to an M.S. in Materials Science and Engineering. Coterminal degree programs are encouraged both for undergraduate majors in Materials Science and Engineering and for undergraduate majors in related disciplines.

Graduate Programs in Materials Science Engineering

Graduate programs lead to the degrees of Master of Science, Engineer, and Doctor of Philosophy. Graduate students can specialize in any of the areas of materials science and engineering.

Learning Outcomes (Graduate)

The purpose of the master’s program is to provide students with the knowledge and skills necessary for a professional career or doctoral studies. This is done through course and laboratory work in solid state fundamentals and materials engineering, and further course work in a technical depth area which may include a master’s Research Report. Typical depth areas include nanocharacterization, electronic and photonic materials, energy materials, nano and biomaterials.

The Ph.D. is conferred upon candidates who have demonstrated substantial scholarship and the ability to conduct independent research. Through course work and guided research, the program prepares students to make original contributions in Materials Science and Engineering and related fields.

Facilities

The department is located in the William F. Durand Building, 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, majority of the faculty, administrative and technical staff, graduate students as well as lecture and seminar rooms. The research facilities are equipped to conduct electrical measurements, mechanical testing of bulk and thin film materials, fracture and fatigue of advanced materials, metallography, optical, scanning, transmission electron microscopy, 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 (CMN (http://www.stanford.edu/group/nanomag_center)), Stanford Nanocharacterization Laboratory (SNL (http://www.stanford.edu/group/snl)) and Nanoscale Prototyping Laboratory (NPL (http://npl-web.stanford.edu); joint facility with Mechanical Engineering in Building 530). The department maintains a microcomputer cluster for its students, which is 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 Stanford Nanofabrication Facility (SNF (http://snf.stanford.edu)), Geballe Laboratory for Advanced Materials (GLAM (http://stanford.edu/group/glam)), and Stanford Synchrotron Radiation Laboratory (SSRL (http://www-ssrl.slac.stanford.edu)).

The Stanford Nanofabrication Facility (SNF) is a laboratory joining government and industrially funded research on microelectronic materials, devices, and systems. It houses a 10,000 sq. ft., 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, the Center for Integrated Systems (CIS (http://cis.stanford.edu)) provides start-up research funds and maintains a fellow-mentor program with industry.

Bachelor of Science in Materials Science and Engineering

Mission Statement

The mission of the Materials Science and Engineering Program is to provide students with a strong foundation in materials science and engineering. The program's curriculum places special emphasis on the fundamental scientific and engineering principles which underlie the knowledge and implementation of materials structure, processing, properties, and performance of all classes of materials used in engineering systems. Courses in the program develop students' knowledge of modern materials science and engineering and teach them to apply this knowledge analytically to create effective and novel solutions to practical problems. The program prepares students for careers in industry or for further study in graduate school.

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 Bachelor of Science in Materials Science and Engineering section of this bulletin as well as the School of Engineering Undergraduate Handbook (http://www.stanford.edu/group/ughb/cgi-bin/handbook/index.php/Main_Page). The University’s basic requirements for the bachelor’s degree are discussed in the Bachelor of Science in Materials Science and Engineering 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.

Students interested in the minor should see the Materials Science and Engineering Minor section of this bulletin.

Materials Science and Engineering (MATSCI)

Completion of the undergraduate program in Materials Science and Engineering leads to the conferral of the Bachelor of Science in Materials Science and Engineering.

Mission of the Undergraduate Program in Materials Science and Engineering

The mission of the undergraduate program in Materials Science and Engineering is to provide students with a strong foundation in materials science and engineering with emphasis on the fundamental scientific and engineering principles which underlie the knowledge and implementation of material structure, processing, properties, and performance of all classes of materials used in engineering systems. Courses in the program develop students' knowledge of modern materials science and engineering, teach them to apply this knowledge analytically to create effective and novel solutions to practical problems, and develop their communication skills and ability to work collaboratively. The program prepares students for careers in industry and for further study in graduate school.

The B.S. in Materials Science and Engineering provides training for the materials engineer and also preparatory training for graduate work in materials science. Capable undergraduates are encouraged to take at least one year of graduate study to extend their course work through the coterminal degree program which leads to an M.S. in Materials Science and Engineering. Coterminal degree programs are encouraged both for undergraduate majors in Materials Science and Engineering and for undergraduate majors in related disciplines.

Requirements

		Units
Mathematics		
20 units minimum; see Basic Requirement 1 [1]		
Select one of the following:		5
MATH 51	Linear Algebra and Differential Calculus of Several Variables	
CME 100/ ENGR 154	Vector Calculus for Engineers	
Select one of the following:		5
MATH 52	Integral Calculus of Several Variables	
CME 104/ ENGR 155B	Linear Algebra and Partial Differential Equations for Engineers	
Select one of the following:		5
MATH 53	Ordinary Differential Equations with Linear Algebra	
CME 102/ ENGR 155A	Ordinary Differential Equations for Engineers	
One additional course		5
Science		
20 units minimum; see Basic Requirement 2 [2]		20
Must include a full year of physics or chemistry, with one quarter of study in the other subject.		
Technology in Society		
One course; see Basic Requirement 3 [3]		3-5
Engineering Fundamentals		
Three courses minimum; see Basic Requirement 4 [4]		
Select one of the following:		4
ENGR 50	Introduction to Materials Science, Nanotechnology Emphasis [4]	
ENGR 50E	Introduction to Materials Science, Energy Emphasis [4]	
ENGR 50M	Introduction to Materials Science, Biomaterials Emphasis [4]	
At least two additional courses		6-9
Materials Science and Engineering Depth		
Materials Science Fundamentals:		
MATSCI 153	Nanostructure and Characterization	4
MATSCI 154	Thermodynamic Evaluation of Green Energy Technologies [5]	4
MATSCI 155	Nanomaterials Synthesis	4
MATSCI 157	Quantum Mechanics of Nanoscale Materials	4
Two of the following courses:		8
MATSCI 151	Microstructure and Mechanical Properties	
MATSCI 152	Electronic Materials Engineering	
MATSCI 156	Solar Cells, Fuel Cells, and Batteries: Materials for the Energy Solution	
MATSCI 190	Organic and Biological Materials	
MATSCI 192	Materials Chemistry	
MATSCI 193	Atomic Arrangements in Solids	
MATSCI 194	Thermodynamics and Phase Equilibria	
MATSCI 195	Waves and Diffraction in Solids	
MATSCI 196	Defects in Crystalline Solids	
MATSCI 197	Rate Processes in Materials	
MATSCI 198	Mechanical Properties of Materials	
MATSCI 199	Electronic and Optical Properties of Solids	
Engineering Depth		16
One of the following courses:		
MATSCI 161	Nanocharacterization Laboratory (WIM)	
MATSCI 164	Electronic and Photonic Materials and Devices Laboratory (WIM)	
Three of the following courses:		
MATSCI 160	Nanomaterials Laboratory	
MATSCI 162	X-Ray Diffraction Laboratory	
MATSCI 163	Mechanical Behavior Laboratory	
MATSCI 165	Nanoscale Materials Physics Computation Laboratory	
Focus Area Options [6]		10

1. Basic Requirement 1 (20 units minimum): see a list of approvedMath Courses (http://www.stanford.edu/group/ughb/cgi-bin/handbook/index.php/Approved_Courses).
2. Basic Requirement 2 (20 units minimum): see a list of approvedScience Courses (http://www.stanford.edu/group/ughb/cgi-bin/handbook/index.php/Approved_Courses).
3. Basic Requirement 3 (one course minimum): see a list of approvedTechnology in Society Courses (http://www.stanford.edu/group/ughb/cgi-bin/handbook/index.php/Approved_Courses).
4. Basic Requirement 4 (3 courses minimum): see a list of approvedEngineering Fundamentals (http://www.stanford.edu/group/ughb/cgi-bin/handbook/index.php/Approved_Courses)Courses. If bothENGR 50 (p. 1) Introduction to Materials Science, Nanotechnology Emphasis,ENGR 50E (p. 1) Introduction to Materials Science - Energy Emphasis, and/orENGR 50M (p. 1) Introduction to Materials Science, Biomaterials Emphasisare taken, one may be used for the Materials Science Fundamentals requirement.

[5] ENGR 30 (p. 1) Engineering Thermodynamicsmay be substituted forMATSCI 154 (p. 1) Thermodynamic Evaluation of Green Energy Technologiesas long as the total MATSCI program units total 50 or more.

[6] Focus Area Options: 10 units from one of the following Focus Area Options below.

Focus Area Options

Bioengineering (10 units minimum)	
BIOE 220	Introduction to Imaging and Image-based Human Anatomy
BIOE 281	Biomechanics of Movement
BIOE 284B	Cardiovascular Bioengineering
BIOE 333	Interfacial Phenomena and Bionanotechnology
BIOE 381	Orthopaedic Bioengineering
MATSCI 190	Organic and Biological Materials
MATSCI 380	Nano-Biotechnology
MATSCI 381	Biomaterials in Regenerative Medicine
MATSCI 382	Biochips and Medical Imaging
Chemical Engineering (10 units minimum)	
CHEM 171	Physical Chemistry I
CHEMENG 130	Separation Processes
CHEMENG 140	Micro and Nanoscale Fabrication Engineering
CHEMENG 150	Biochemical Engineering
CHEMENG 160	Polymer Science and Engineering
Chemistry (10 units minimum)	
CHEM 151	Inorganic Chemistry I
CHEM 153	Inorganic Chemistry II
CHEM 171	Physical Chemistry I
CHEM 173	Physical Chemistry II
CHEM 175	Physical Chemistry III
CHEM 181	Biochemistry I
CHEM 183	Biochemistry II
CHEM 185	Biophysical Chemistry
Electronics & Photonics (10 units minimum)	
EE 101A	Circuits I
EE 101B	Circuits II
EE 102A	Signal Processing and Linear Systems I
EE 102B	Signal Processing and Linear Systems II
EE 116	Semiconductor Device Physics
EE 134	Introduction to Photonics
EE 136	Introduction to Nanophotonics and Nanostructures
EE 142	Engineering Electromagnetics (Formerly EE 141)
MATSCI 343	Organic Semiconductors for Electronics and Photonics
Energy Technology (10 units minimum)	
EE 293B	Fundamentals of Energy Processes
MATSCI 156	Solar Cells, Fuel Cells, and Batteries: Materials for the Energy Solution
MATSCI 302	Solar Cells
MATSCI 303	Principles, Materials and Devices of Batteries
ME 260	Fuel Cell Science and Technology
Materials Characterization Techniques (10 units minimum)	
MATSCI 320	Nanocharacterization of Materials
MATSCI 321	Transmission Electron Microscopy
MATSCI 322	Transmission Electron Microscopy Laboratory
MATSCI 323	Thin Film and Interface Microanalysis
MATSCI 326	X-Ray Science and Techniques
Mechanical Behavior & Design (10 units minimum)	
AA 240A	Analysis of Structures
AA 240B	Analysis of Structures
AA 256	Mechanics of Composites
MATSCI 198	Mechanical Properties of Materials
MATSCI 358	Fracture and Fatigue of Materials and Thin Film Structures
ME 80	Mechanics of Materials
or CEE 101A	Mechanics of Materials
ME 203	Design and Manufacturing
ME 294	
Nanoscience (10 units minimum)	
BIOE 333	Interfacial Phenomena and Bionanotechnology
EE 136	Introduction to Nanophotonics and Nanostructures
ENGR 240	Introduction to Micro and Nano Electromechanical Systems
MATSCI 316	Nanoscale Science, Engineering, and Technology
MATSCI 320	Nanocharacterization of Materials
MATSCI 346	Nanophotonics
MATSCI 347	Introduction to Magnetism and Magnetic Nanostructures
MATSCI 380	Nano-Biotechnology
Physics (10 units minimum)	
PHYSICS 70	Foundations of Modern Physics
PHYSICS 110	Advanced Mechanics
PHYSICS 120	Intermediate Electricity and Magnetism I
PHYSICS 121	Intermediate Electricity and Magnetism II
PHYSICS 130	Quantum Mechanics I
PHYSICS 131	Quantum Mechanics II
PHYSICS 134	Advanced Topics in Quantum Mechanics
PHYSICS 170	Thermodynamics, Kinetic Theory, and Statistical Mechanics I
PHYSICS 171	Thermodynamics, Kinetic Theory, and Statistical Mechanics II
PHYSICS 172	Solid State Physics
Self-Defined Option (10 units minimum)	
Petition for a self-defined cohesive program.	

For additional information and sample programs see the Handbook for Undergraduate Engineering Programs (http://ughb.stanford.edu).

Materials Science and Engineering (MATSCI) Minor

A minor in Materials Science and Engineering allows interested students to explore the role of materials in modern technology and to gain an understanding of the fundamental processes that govern materials behavior.

The following courses fulfill the minor requirements:

		Units
Engineering Fundamentals		
Select one of the following:		4
ENGR 50	Introduction to Materials Science, Nanotechnology Emphasis	

ENGR 50E	Introduction to Materials Science, Energy Emphasis	
ENGR 50M	Introduction to Materials Science, Biomaterials Emphasis	
Materials Science Fundamentals and Engineering Depth		
Select six of the following:		24
MATSCI 151	Microstructure and Mechanical Properties	
MATSCI 152	Electronic Materials Engineering	
MATSCI 153	Nanostructure and Characterization	
MATSCI 154	Thermodynamic Evaluation of Green Energy Technologies	
MATSCI 155	Nanomaterials Synthesis	
MATSCI 156	Solar Cells, Fuel Cells, and Batteries: Materials for the Energy Solution	
MATSCI 157	Quantum Mechanics of Nanoscale Materials	
MATSCI 160	Nanomaterials Laboratory	
MATSCI 161	Nanocharacterization Laboratory	
MATSCI 162	X-Ray Diffraction Laboratory	
MATSCI 163	Mechanical Behavior Laboratory	
MATSCI 164	Electronic and Photonic Materials and Devices Laboratory	
MATSCI 165	Nanoscale Materials Physics Computation Laboratory	
MATSCI 190	Organic and Biological Materials	
MATSCI 192	Materials Chemistry	
MATSCI 193	Atomic Arrangements in Solids	
MATSCI 194	Thermodynamics and Phase Equilibria	
MATSCI 195	Waves and Diffraction in Solids	
MATSCI 196	Defects in Crystalline Solids	
MATSCI 197	Rate Processes in Materials	
MATSCI 198	Mechanical Properties of Materials	
MATSCI 199	Electronic and Optical Properties of Solids	
Total Units		**28**

Master of Science in Materials Science Engineering

The University's basic requirements for the M.S. degree are discussed in the "Graduate Degrees (http://exploredegrees.stanford.edu/graduatedegrees)" 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. A Master's Program Proposal (http://studentaffairs.stanford.edu/sites/default/files/registrar/files/progpropma.pdf) form 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 revisions to the master's program proposal must be submitted no later than one academic quarter prior to the quarter of expected 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 and Engineering (MATSCI) course work, including core and lab courses specified below, all taken for a letter grade. Research units, one-unit seminars, MATSCI 299 Practical Training 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. Of these 30 units Materials Science requirements, students must include a or b.
   a. three classes from MATSCI 201-210 core courses and three MATSCI 171, 172, 173, 174, 175 laboratory courses. One laboratory requirement may be fulfilled by taking a lab course from another engineering department.

		Units
Select three of the following core courses:		
MATSCI 202	Materials Chemistry	3
MATSCI 203	Atomic Arrangements in Solids	3
MATSCI 204	Thermodynamics and Phase Equilibria	3
MATSCI 205	Waves and Diffraction in Solids	3
MATSCI 206	Defects in Crystalline Solids	3
MATSCI 207	Rate Processes in Materials	3
MATSCI 208	Mechanical Properties of Materials	3
MATSCI 209	Electronic and Optical Properties of Solids	3
MATSCI 210	Organic and Biological Materials	3
Total core course units		9
Select three of the following lab courses:		
MATSCI 171	Nanocharacterization Laboratory	3
MATSCI 172	X-Ray Diffraction Laboratory	3
MATSCI 173	Mechanical Behavior Laboratory	3
MATSCI 174	Electronic and Photonic Materials and Devices Laboratory	3
MATSCI 175	Nanoscale Materials Physics Computation Laboratory	3
One laboratory requirment may be fulfilled by taking lab courses from another engineering dept.		
Total lab course units		9
TOTAL		18

   b. four classes from MATSCI 201-210 core courses and two MATSCI 171, 172, 173, 174, 175 laboratory courses. One laboratory requirement may be fulfilled by taking a lab course from another engineering department.

		Units
Select four of the following core courses:		
MATSCI 202	Materials Chemistry	3
MATSCI 203	Atomic Arrangements in Solids	3
MATSCI 204	Thermodynamics and Phase Equilibria	3
MATSCI 205	Waves and Diffraction in Solids	3
MATSCI 206	Defects in Crystalline Solids	3
MATSCI 207	Rate Processes in Materials	3
MATSCI 208	Mechanical Properties of Materials	3
MATSCI 209	Electronic and Optical Properties of Solids	3
MATSCI 210	Organic and Biological Materials	3
Total core course units		12
Select two of the following lab courses:		
MATSCI 171	Nanocharacterization Laboratory	3
MATSCI 172	X-Ray Diffraction Laboratory	3
MATSCI 173	Mechanical Behavior Laboratory	3
MATSCI 174	Electronic and Photonic Materials and Devices Laboratory	3
MATSCI 175	Nanoscale Materials Physics Computation Laboratory	3
One laboratory requirment may be fulfilled by taking lab courses from another engineering dept.		

Total lab course units	6
TOTAL	18

3. 15 units of approved course electives to result in a technically cohesive program. Of the 15 units of elective courses:
    a. 12 units must be MATSCI.
    b. 12 units must be taken for a letter grade (except for those submitting a M.S. thesis report).
    c. a maximum of three units may be seminars.
    d. if writing a master's thesis report, a minimum of 6 and a maximum of 15 units of MATSCI 200 Master's Research may be counted. Master's research units may be counted only if writing a M.S. thesis report. The final version of the thesis report must be signed off by two faculty and submitted to student services manager by last day of classes of the graduation quarter. See student services manager for details and approval.
    e. a maximum of three units may be undergraduate units, but not courses below the 100 level offering.
    f. a maximum of five units may be used for a foreign language course (not including any remedial English or courses in the student's native language if other than English). Students must plan to enroll in an upper level designation of a foreign language course offering.
    g. the combination of seminar, undergraduate, and language units may not exceed six units total.
    h. the combination of research, seminar, undergraduate, and language units may not exceed 15 units total.
    i. activity units may not be counted toward M.S. degree.
4. A minimum grade point average (GPA) of 2.75 for degree course work.

All proposed degree programs are subject to approval by student's academic adviser, and department's student services manager, who has responsibility for assuring that each proposal is a technically cohesive program. The M.S. degree is expected to be completed within two years during the University's candidacy period for completion of a master's degree.

Master's Thesis Report

Students wishing to take this option must consult with a MATSCI faculty member initially. Out of the 45 units M.S. degree requirements, 6-15 units may be taken in Materials Science Master's research by enrolling in MATSCI 200. Students using 15 units of research toward the degree must participate in a more complex and demanding research project than those using lesser units.

The M.S. thesis report must be approved and signed off by two faculty members. In general, one is student's research adviser, if adviser is a non MATSCI faculty member, a second MATSCI faculty is required to sign off on the thesis report. Consult with student services manager about faculty criteria, and requirements. Three copies of M.S. thesis report in final format should be submitted to two faculty advisers, and the department. The report is not an official University thesis but is intended to demonstrate to the department and faculty student's ability to conduct and report a directed research.

As a general guide line, a 6-9 units of master's research is a normal load for most students. The report should reflect the number of units taken. For instance, 3-4 laboratory reports are required for a 3-unit laboratory course. Accordingly, the level expected for 9 units of research would be at least equivalent to three such courses.

Students are advised to submit their thesis draft to faculty adviser readers by the end of fifth week of the quarter in which the units are to be assigned to allow time for faculty comments and revisions. A collated final version of the thesis report should be submitted to faculty and student services manager by last day of classes of student's graduation quarter. The appropriate grade for satisfactory progress in the research project prior to submission of the final report is 'N' (continuing); the 'S' (Satisfactory) final grade is given only when the report is fully approved and signed off by both faculty members.

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 thesis report is not submitted, units in MATSCI 200 Master's Research cannot be applied to the department's requirement of 45 units for the conferral of 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 Graduate Programs in the "School of Engineering (http://exploredegrees.stanford.edu/schoolofengineering)" section of this bulletin.

Petition Process for Transfer from M.S. to Ph.D. Degree Program

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

A student in the terminal M.S. program may petition to be admitted to the Ph.D. program by filing an M.S. to Ph.D petition form. Petition must include a one-page statement of purpose explaining why the student wishes to transfer to the Ph.D. program, most recent unofficial transcript, and two letters of recommendation from members of the Stanford faculty, including one from the student's prospective research adviser and at least one from a Materials Science faculty member belonging to the Academic Council. The M.S. to Ph.D. petition to transfer should be submitted to the student services manager by June of the first year in the M.S. program. Students who wish to submit a petition to the Ph.D. degree, should plan to complete at least six of the MATSCI 200 series (including MATSCI 203 Atomic Arrangements in Solids, MATSCI 204 Thermodynamics and Phase Equilibria, MATSCI 207 Rate Processes in Materials) core courses during their first year of admission. A grade point average (GPA) of 3.5 or better in the core courses is requirement.

Transferring to the Ph.D. program is a competitive process and only highly qualified M.S. students may be admitted. Student's original application to the graduate program as well as the materials provided for the transfer petition are reviewed. Students must adhere to requirements for the terminal M.S. degree, and plan to confer the M.S. degree in the event that the Ph.D. petition to transfer is not approved.

Coterminal Master of Science Program in Materials Science and Engineering

Stanford undergraduates who wish to continue their studies for the Master of Science degree in Materials Science and Engineering through 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 eight weeks before the start of the proposed admit quarter. The application must give evidence that student possesses a potential for strong academic performance at the graduate level. Scores from the Graduate Record Examination (GRE) General Test must be reported before action can be taken on an application.

Materials science is a highly integrated and interdisciplinary subject, therefore students of any engineering or science undergraduate major are encouraged to apply.

Information and other requirements pertaining to the Coterminal program in Materials Science and Engineering may be obtained from the department's student services manager.

University Coterminal Requirements

Coterminal master's degree candidates are expected to complete all master's degree requirements as described in this bulletin. University requirements for the coterminal master's degree are described in the "Coterminal Master's Program (http://exploredegrees.stanford.edu/cotermdegrees)" section. University requirements for the master's degree are described in the "Graduate Degrees (http://exploredegrees.stanford.edu/graduatedegrees/#masterstext)" section of this bulletin.

After accepting admission to this coterminal master's degree program, students may request transfer of courses from the undergraduate to the graduate career to satisfy requirements for the master's degree. Transfer of courses to the graduate career requires review and approval of both the undergraduate and graduate programs on a case by case basis.

In this master's program, courses taken during or after the first quarter of the sophomore year are eligible for consideration for transfer to the graduate career; the timing of the first graduate quarter is not a factor. No courses taken prior to the first quarter of the sophomore year may be used to meet master's degree requirements.

Course transfers are not possible after the bachelor's degree has been conferred.

The University requires that the graduate adviser be assigned in the student's first graduate quarter even though the undergraduate career may still be open. The University also requires that the Master's Degree Program Proposal be completed by the student and approved by the department by the end of the student's first graduate quarter.

Engineer in Materials Science Engineering

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 (no research units, seminars, colloquia, and MATSCI 400 Participation in Materials Science Teaching, 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.

The Engineer thesis must be approved and signed off by two Academic Council faculty members, one must be a MATSCI faculty member.

Doctor of Philosophy in Materials Science Engineering

The University's basic requirements for the Ph.D. degree are outlined in the "Graduate Degrees (http://exploredegrees.stanford.edu/graduatedegrees)" section of this bulletin.

The Ph.D. degree is awarded after the completion of a minimum of 135 units of graduate work as well as satisfactory completion of any additional University requirements. Degree requirements for the department are as follows:

		Units
Core Courses [1]		30
EE 222	Applied Quantum Mechanics I	
MATSCI 202	Materials Chemistry	
MATSCI 203	Atomic Arrangements in Solids	
MATSCI 204	Thermodynamics and Phase Equilibria	
MATSCI 205	Waves and Diffraction in Solids	
MATSCI 206	Defects in Crystalline Solids	
MATSCI 207	Rate Processes in Materials	
MATSCI 208	Mechanical Properties of Materials	
MATSCI 209	Electronic and Optical Properties of Solids	
MATSCI 210	Organic and Biological Materials	
Five Elective Graduate Technical Courses [2]		15
Materials Science Colloquia [3]		3
MATSCI 230	Materials Science Colloquium (Autumn 2014)	
MATSCI 230	Materials Science Colloquium (Winter 2015)	
MATSCI 230	Materials Science Colloquium (Spring 2015)	
Research & Electives		87
75 Units of MATSCI 300: Ph.D. Research		
12 Units of Electives [4]		

1 At least six of these courses must be taken during the first year (including MATSCI 203 (http://exploredegrees.stanford.edu/schoolofengineering/materialsscienceandengineering) Atomic Arrangements in Solids, MATSCI 204 (http://exploredegrees.stanford.edu/schoolofengineering/materialsscienceandengineering) Thermodynamics and Phase Equilibria, and MATSCI 207 (http://exploredegrees.stanford.edu/schoolofengineering/materialsscienceandengineering) Rate Processes in Materials) . All core courses must be completed for a letter grade, and taken during the first two years in the program.

2 Elective technical courses must be in areas related directly to student's research interest in Materials Science and Engineering, and may not include MATSCI 230 (http://exploredegrees.stanford.edu/schoolofengineering/materialsscienceandengineering) Materials Science Colloquium, MATSCI 299 (http://exploredegrees.stanford.edu/schoolofengineering/materialsscienceandengineering) Practical Training, MATSCI 300 (http://exploredegrees.stanford.edu/schoolofengineering/materialsscienceandengineering) Ph.D. Research or MATSCI 400 (http://exploredegrees.stanford.edu/schoolofengineering/materialsscienceandengineering) Participation in Materials Science Teaching. All courses must be completed for a letter grade.

3 Materials Science & Engineering Ph.D. students are required to take MATSCI 230 (http://exploredegrees.stanford.edu/schoolofengineering/materialsscienceandengineering) Materials Science Colloquium during each quarter of their first year. Attendance is required, roll is taken, and more than two absences results to an automatic "No Pass" grade.

4 May include other engineering courses, or MATSCI 400 (http://exploredegrees.stanford.edu/schoolofengineering/materialsscienceandengineering) Participation in Materials Science Teaching or a maximum of 3 units MATSCI 299 (http://exploredegrees.stanford.edu/schoolofengineering/materialsscienceandengineering) Practical Training

- Students must consult with their academic adviser on Ph.D. course selection planning. For students with a non-MATSCI research adviser, the MATSCI academic/co-adviser must also approve the list of proposed courses. Any proposed deviations from the requirements can only be considered by petition.
- Ph.D. students are required to apply for and have conferred a MATSCI M.S. degree normally by the end of their third year of studies. A Graduate Program Authorization Petition (in Axess) and an M.S. Program Proposal (http://studentaffairs.stanford.edu/sites/default/files/registrar/files/progpropma.pdf) must be submitted after taking the Ph.D. qualifying examination.
- A departmental oral qualifying examination must be passed by the end of January of the second year. A grade point average (GPA) of 3.5 in core courses MATSCI 201-210 is required for admission to the Ph.D. qualifying examination. Students who have passed the Ph.D. qualifying examination are required to complete the Application for Candidacy to the Ph.D.degree by June of the second year after passing the qualifying examination. Final changes in the Application for Candidacy form must be submitted no later than one academic quarter prior to the TGR status.
- Maintain a cumulative GPA of 3.0 in all courses taken at Stanford.
- Students must present the results of their research dissertation at the University Ph.D. oral defense examination.
- Current students subject to either this set of requirements or a prior set must obtain the approval of their adviser before filing a revised program sheet, and should as far as possible adhere to the intent of the new requirements.
- Students may refer the list of "Advanced Specialty Courses and Cognate Courses" provided below as guidelines for their selection of technical elective units. As noted above, academic adviser approval is required.
- 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 Ph.D. degree requirement units.
- Students may propose a petition for exemption from a required core course if they have taken a similar course in the past. To petition, a student must consult and obtain academic and/or research adviser approval, and consent of the instructor of the proposed core course. To assess a student's level of knowledge, the instructor may provide an oral or written examination on the subject matter. The student must pass the examination in order to be exempt from core course requirement. If the petition is approved, the student is required to complete the waived number of units by taking other relevant upper level MATSCI courses.

Advanced Specialty Courses

		Units
Biomaterials		
APPPHYS 292 (Offered previous years, may be counted)		
BIOPHYS 228	Computational Structural Biology	
CHEMENG 260	Polymer Science and Engineering	
CHEMENG 310	Microhydrodynamics	
CHEMENG 355	Advanced Biochemical Engineering	
ME 284A (Offered previous years, may be counted)		
ME 284B (Offered previous years, may be counted)		
ME 381	Orthopaedic Bioengineering	
ME 385	Tissue Engineering Lab	
ME 457	Fluid Flow in Microdevices	
MATSCI 380	Nano-Biotechnology	
MATSCI 381	Biomaterials in Regenerative Medicine	
MATSCI 382	Biochips and Medical Imaging	
Electronic Materials Processing		
EE 212	Integrated Circuit Fabrication Processes	
EE 216	Principles and Models of Semiconductor Devices	
EE 311	Advanced Integrated Circuits Technology	
EE 316	Advanced VLSI Devices	
EE 410	Integrated Circuit Fabrication Laboratory	
MATSCI 312	New Methods in Thin Film Synthesis	
Materials Characterization		
APPPHYS 216		
CHEMENG 345	Fundamentals and Applications of Spectroscopy	
EE 329 (Not offered in 2013-2014)		
MATSCI 312	New Methods in Thin Film Synthesis	
MATSCI 320	Nanocharacterization of Materials	
MATSCI 321	Transmission Electron Microscopy	
MATSCI 322	Transmission Electron Microscopy Laboratory	
MATSCI 323	Thin Film and Interface Microanalysis	
MatSci 325 (Not offered in 2013-2014)		
MATSCI 326	X-Ray Science and Techniques	
Mechanical Behavior of Solids		
AA 252	Techniques of Failure Analysis	
AA 256	Mechanics of Composites	
MATSCI 251	Microstructure and Mechanical Properties	
MATSCI 353	Mechanical Properties of Thin Films	
MATSCI 358	Fracture and Fatigue of Materials and Thin Film Structures	
ME 335A	Finite Element Analysis	
ME 335B	Finite Element Analysis	
ME 335C	Finite Element Analysis	
ME 340	Theory and Applications of Elasticity	
ME 340A (Offered previous years, may be counted)		
ME 340B (Offered previous years, may be counted)		
ME 345	Fatigue Design and Analysis	
Physics of Solids and Computation		
APPPHYS 272	Solid State Physics	
APPPHYS 273	Solid State Physics II	
EE 222	Applied Quantum Mechanics I	
EE 223	Applied Quantum Mechanics II	
EE 228	Basic Physics for Solid State Electronics	
EE 327	Properties of Semiconductor Materials	
EE 328	Physics of Advanced Semiconductor Devices	
EE 329	The Electronic Structure of Surfaces and Interfaces	
EE 335 (Offered previous years, may be counted)		

MATSCI 331	Atom-based computational methods for materials
MATSCI 343	Organic Semiconductors for Electronics and Photonics
MATSCI 347	Introduction to Magnetism and Magnetic Nanostructures
ME 344A (Offered previous years, may be counted)	
ME 344B (Offered previous years, may be counted)	
Soft Materials	
CHEMENG 260	Polymer Science and Engineering
CHEMENG 310	Microhydrodynamics
CHEMENG 460 (Offered previous years, may be counted)	
MATSCI 343	Organic Semiconductors for Electronics and Photonics
ME 455	Complex Fluids and Non-Newtonian Flows

Ph.D. Minor in Materials Science and Engineering

The University's basic requirements for the Ph.D. minor are outlined in the "Graduate Degrees (http://exploredegrees.stanford.edu/graduatedegrees/#doctoraltext)" section of this bulletin. A minor requires 20 units of graduate work of quality and depth at the 200-level or higher in the Materials Science and Engineering course offering. Courses must be taken for a letter grade. The proposed list of courses must be approved by department's advanced degree committee. Individual programs must be submitted to the student services manager at least one quarter prior to the quarter of the degree conferral. None of the units taken for the Ph.D. minor may overlap with any M.S. degree units.

Emeriti: (Professors) Clayton W. Bates Jr. (https://engineering.stanford.edu/profile/09970823), John C. Bravman, Richard H. Bube (http://engineering.stanford.edu/profile/bube), Theodore H. Geballe (http://www.stanford.edu/dept/app-physics/cgi-bin/person/geballe-theodore-h), Robert A. Huggins (https://engineering.stanford.edu/profile/rhuggins)*, William D. Nix (http://engineering.stanford.edu/profile/nix) *, Oleg D. Sherby (http://engineering.stanford.edu/profile/osherby), John C. Shyne, William A. Tiller (https://engineering.stanford.edu/profile/07098155), Robert L. White (http://www.stanford.edu/group/nanomag_center/faculty.htm#Executive)*, Robert S. Feigelson (http://engineering.stanford.edu/profile/feigel)* *(Professor, Research)*

Chair: Paul C. McIntyre (http://engineering.stanford.edu/profile/bobsinc)

Associate Chair: Shan Xiang Wang (http://engineering.stanford.edu/profile/rhd)

Professors: David M. Barnett (http://engineering.stanford.edu/profile/barnett), Mark L. Brongersma (http://engineering.stanford.edu/profile/markb29), Bruce M. Clemens (http://engineering.stanford.edu/profile/bmc), Reinhold H. Dauskardt (http://engineering.stanford.edu/profile/rhd), Persis S. Drell, Michael D. McGehee (http://engineering.stanford.edu/profile/mmcgehee), Paul C. McIntyre (http://engineering.stanford.edu/profile/pcm1), Friedrich B. Prinz (http://engineering.stanford.edu/profile/fprinz), Robert Sinclair (http://engineering.stanford.edu/profile/bobsinc), Shan X. Wang (http://engineering.stanford.edu/profile/sxwang)

Associate Professors: Yi Cui (http://engineering.stanford.edu/profile/yicui), , Sarah C. Heilshorn, (http://engineering.stanford.edu/profile/sarah7) Nicholas A. Melosh (http://engineering.stanford.edu/profile/nmelosh), Alberto Salleo (http://engineering.stanford.edu/profile/asalleo)

Assistant Professors: William Chueh (http://chuehlab.stanford.edu/Chueh_Lab/Home.html), Jennifer A. Dionne (http://engineering.stanford.edu/profile/jdionne), Aaron M. Lindenberg (http://engineering.stanford.edu/profile/aaronl), Evan J. Reed (http://engineering.stanford.edu/profile/evanreed)

Courtesy Professors: Zhenan Bao, Stacey F. Bent (http://engineering.stanford.edu/profile/sbent), Ian R. Fisher (http://www.stanford.edu/group/fisher/), Curtis W. Frank (http://engineering.stanford.edu/profile/cwfrank), Sanjiv Gambhir (http://med.stanford.edu/profiles/Sanjiv_Gambhir), Geoffrey C. Gurtner (http://med.stanford.edu/profiles/Geoffrey_Gurtner/;jsessionid=D9A8A5AC1B9BC3B2D98B3D6CE95364D8.tc-cap-08), James S. Harris (https://engineering.stanford.edu/profile/jharris-0), Michael T. Longaker (http://med.stanford.edu/profiles/psrl/faculty/michael_longaker), Arunava Majumdar, Yoshio Nishi (http://engineering.stanford.edu/profile/nishiy), James D. Plummer (http://engineering.stanford.edu/profile/plummer), Krishna Saraswat (http://engineering.stanford.edu/profile/saraswat), Jonathan Stebbins (http://engineering.stanford.edu/profile/stohr)

Courtesy Associate Professor: Wei Cai (http://www.stanford.edu/~caiwei), Andrew Spakowitz, Yunzhi Peter Yan

Lecturers: Ann Marshall, Arturas Vailionis (http://simes.stanford.edu/investigator/arturas-vailionis)

Consulting Professors: Turgut M. Gur (http://www.stanford.edu/~turgut), Michael A. Kelly, Rommel Noufi, Kristin Persson, Baylor Triplett, Robert M. White

Consulting Associate Professors: Geraud Jean-Michel Dubois (http://researcher.watson.ibm.com/researcher/view.php?person=us-gdubois)

Acting Assistant Professors: Renee M. Sher

Visiting Professors: Clarence Tee

* Recalled to active duty.

Cognate Courses

		Units
AA 252	Techniques of Failure Analysis	3
AA 256	Mechanics of Composites	3
APPPHYS 216		
APPPHYS 270	Magnetism and Long Range Order in Solids	3
APPPHYS 272	Solid State Physics	3
APPPHYS 273	Solid State Physics II	3
APPPHYS 292 (Offered previous years, may be counted)		
BIOPHYS 228	Computational Structural Biology	3
CHEMENG 260	Polymer Science and Engineering	3
CHEMENG 310	Microhydrodynamics	3
CHEMENG 345	Fundamentals and Applications of Spectroscopy	3
CHEMENG 355	Advanced Biochemical Engineering	3
CHEMENG 460 (Offered previous years, may be counted)		
EE 212	Integrated Circuit Fabrication Processes	3
EE 216	Principles and Models of Semiconductor Devices	3
EE 222	Applied Quantum Mechanics I	3
EE 223	Applied Quantum Mechanics II	3
EE 228	Basic Physics for Solid State Electronics	3
EE 311	Advanced Integrated Circuits Technology	3
EE 312 (Offered in previous years, may be counted)		
EE 316	Advanced VLSI Devices	3
EE 327	Properties of Semiconductor Materials	3
EE 328	Physics of Advanced Semiconductor Devices	3
EE 329	The Electronic Structure of Surfaces and Interfaces	3
EE 335 (Offered in previous years, may be counted)		

EE 410	Integrated Circuit Fabrication Laboratory	3-4
ENGR 31	Chemical Principles with Application to Nanoscale Science and Technology	4
ENGR 50	Introduction to Materials Science, Nanotechnology Emphasis	4
ENGR 50E	Introduction to Materials Science, Energy Emphasis	4
ENGR 50M	Introduction to Materials Science, Biomaterials Emphasis	4
ME 284A (Offered in previous years, may be counted)		
ME 284B (Offered in previous years, may be counted)		
ME 329 (Offered in previous years, may be counted)		
ME 335A	Finite Element Analysis	3
ME 335B	Finite Element Analysis	3
ME 335C	Finite Element Analysis	3
ME 340A (Offered in previous years, may be counted)		
ME 340B (Offered in previous years, may be counted)		
ME 344A (Offered in previous years, may be counted)		
ME 344B (Offered in previous years, may be counted)		
ME 345	Fatigue Design and Analysis	3
ME 381	Orthopaedic Bioengineering	3
ME 385	Tissue Engineering Lab	1-2
ME 455	Complex Fluids and Non-Newtonian Flows	3
ME 457	Fluid Flow in Microdevices	3
PHYSICS 230	Graduate Quantum Mechanics I	3
PHYSICS 231	Graduate Quantum Mechanics II	3

Courses

MATSCI 10SC. Diamonds from Peanut Butter: Material Technologies and Human History. 2 Units.
Technological importance of materials in history is captured in names: the Stone Age, Bronze Age, Iron Age, and now the Information Age or the Silicon Age. How materials have played, and continue to play, pivotal roles in the development of new technologies.

MATSCI 11SC. Energy Technologies for a Sustainable Future. 2 Units.
Wondering what the buzz is about sustainability, renewable energy, and clean fuels? Meeting the world's growing energy needs in a sustainable fashion is one of the most pressing problems of our time. This class will introduce the scope of the energy problem and define some of the options for sustainable energy. We will look into the scientific basis of sustainable energy technologies, such as solar cells, which convert the energy of the sun directly into electricity, and fuel cells, which convert chemical energy directly into electricity. Other topics will include biofuels, i.e., fuel derived from plant matter, and clean fuels such as hydrogen. The course will emphasize the fundamental science behind the devices and highlight some of the cutting-edge technological issues that are currently being explored. Assigned reading will include books on global energy issues as well as technical reading on the science and engineering of sustainable energy technologies. We will visit several local energy-technology companies, and students will have hands-on lab experience with solar cells, fuel cells, and generators. Students are expected to participate in classroom discussions, attend field trips, carry out laboratory experiments, and complete homework assignments, including a term paper.

MATSCI 81N. Bioengineering Materials to Heal the Body. 3 Units.
Preference to freshmen. How scientists and engineers are designing new materials for surgeon to use in replacing body parts such as heart tissue or the spinal cord. How cells, in the body and transplanted stem cells, communicate with implanted materials. Real-world examples of materials developed for tissue engineering and regenerative medicine therapies. Students identify a clinically important disease or injury that requires a better material, research approaches to the problem, and debate possible engineering solutions.

MATSCI 82N. Science of the Impossible. 3 Units.
Imagine a world where cancer is cured with light, objects can be made invisible, and teleportation is allowed through space and time. The future once envisioned by science fiction writers is now becoming a reality, thanks to advances in materials science and engineering. This seminar will explore 'impossible' technologies - those that have shaped our past and those that promise to revolutionize the future. Attention will be given to both the science and the societal impact of these technologies. We will begin by investigating breakthroughs from the 20th century that seemed impossible in the early 1900s, such as the invention of integrated circuits and the discovery of chemotherapy. We will then discuss the scientific breakthroughs that enabled modern 'impossible' science, such as photodynamic cancer therapeutics, invisibility, and psychokinesis through advanced mind-machine interfaces. Lastly, we will explore technologies currently perceived as completely impossible and brainstorm the breakthroughs needed to make such science fiction a reality. The course will include introductory lectures and in-depth conversations based on readings. Students will also be given the opportunity to lead class discussions on a relevant 'impossible science' topic of their choosing.

MATSCI 100. Undergraduate Independent Study. 1-3 Unit.
Independent study in materials science under supervision of a faculty member.

MATSCI 150. Undergraduate Research. 3-6 Units.
Participation in a research project.

MATSCI 151. Microstructure and Mechanical Properties. 3-4 Units.
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: MATSCI 163. Undergraduates register in 151 for 4 units; graduates register for 251 in 3 units.
Same as: MATSCI 251

MATSCI 152. Electronic Materials Engineering. 4 Units.
Materials science and engineering for electronic device applications. Kinetic molecular theory and thermally activated processes; band structure; electrical conductivity of metals and semiconductors; intrinsic and extrinsic semiconductors; elementary p-n junction theory; operating principles of light emitting diodes, solar cells, thermoelectric coolers, and transistors. Semiconductor processing including crystal growth, ion implantation, thin film deposition, etching, lithography, and nanomaterials synthesis.

MATSCI 153. Nanostructure and Characterization. 4 Units.
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; their applications to study such nanostructures.

MATSCI 154. Thermodynamic Evaluation of Green Energy Technologies. 4 Units.
Understand the thermodynamics and efficiency limits of modern green technologies such as carbon dioxide capture from air, fuel cells, batteries, and solar-thermal power.

MATSCI 155. Nanomaterials Synthesis. 4 Units.
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.

MATSCI 156. Solar Cells, Fuel Cells, and Batteries: Materials for the Energy Solution. 3-4 Units.
Operating principles and applications of emerging technological solutions to the energy demands of the world. The scale of global energy usage and requirements for possible solutions. Basic physics and chemistry of solar cells, fuel cells, and batteries. Performance issues, including economics, from the ideal device to the installed system. The promise of materials research for providing next generation solutions. Undergraduates register in 156 for 4 units; graduates register in 256 for 3 units.
Same as: EE 293A, ENERGY 293A, MATSCI 256

MATSCI 157. Quantum Mechanics of Nanoscale Materials. 4 Units.
Introduction to quantum mechanics and its application to the properties of materials. No prior background beyond a working knowledge of calculus and high school physics is presumed. Topics include: The Schrodinger equation and applications to understanding of the properties of quantum dots, semiconductor heterostructures, nanowires, and bulk solids. Tunneling processes and applications to nanoscale devices; the scanning tunneling microscope, and quantum cascade lasers. Simple models for the electronic properties and band structure of materials including semiconductors, insulators and metals and applications to semiconductor devices. Time-dependent perturbation theory and interaction of light with materials with applications to laser technology.

MATSCI 159Q. Japanese Companies and Japanese Society. 3 Units.
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.
Same as: ENGR 159Q

MATSCI 160. Nanomaterials Laboratory. 4 Units.
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 self-assembled monolayers. 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.

MATSCI 161. Nanocharacterization Laboratory. 3-4 Units.
Students use optical microscopy, x-ray diffraction, scanning electron microscopy, x-ray photoelectron spectroscopy, atomic force microscopy and other techniques to characterize recently discovered perovskite semiconductors that can be used to make highly efficient solar cells. This course fulfills the Writing in the Major Requirement for MSE undergrads. Instruction on writing, statistics, generating effective plots with curve fits, using databases to find information and giving oral scientific presentations is given. Instruction on characterization techniques is provided, but it is expected that the students will have already taken a course like MATSCI 153 that covers the fundamentals of the techniques. The emphasis on this course is on doing nanocharacterization experiments and writing up the results. Undergraduates register for 161 for 4 units; graduates register for 171 for 3 units.
Same as: MATSCI 171

MATSCI 162. X-Ray Diffraction Laboratory. 3-4 Units.
Experimental x-ray diffraction techniques for microstructural analysis of materials, emphasizing powder and single-crystal techniques. Diffraction from epitaxial and polycrystalline thin films, multilayers, and amorphorous materials using medium and high resolution configurations. Determination of phase purity, crystallinity, relaxation, stress, and texture in the materials. Advanced experimental x-ray diffraction techniques: reciprocal lattice mapping, reflectivity, and grazing incidence diffraction. Enrollment limited to 20. Undergraduates register for 162 for 4 units; graduates register for 172 for 3 units.
Same as: MATSCI 172, PHOTON 172

MATSCI 163. Mechanical Behavior Laboratory. 3-4 Units.
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. Prerequisite: ENGR 50. Undergraduates register for 163 in 4 units; graduates register in 173 for 3 units.
Same as: MATSCI 173

MATSCI 164. Electronic and Photonic Materials and Devices Laboratory. 3-4 Units.
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. Prerequisite: 152 or 199 or consent of instructor. Undergraduates register in 164 for 4 units; graduates register in 174 for 3 units.
Same as: MATSCI 174

MATSCI 165. Nanoscale Materials Physics Computation Laboratory. 3-4 Units.
Computational exploration of fundamental topics in materials science using Java-based computation and visualization tools. Emphasis is on the atomic-scale origins of macroscopic materials phenomena. Simulation methods include molecular dynamics and Monte Carlo with applications in thermodynamics, kinetics, and topics in statistical mechanics. Required prerequisites: Freshman-level physics, undergraduate thermodynamics. Undergraduates register for 165 for 4 units; graduates register for 175 for 3 units.
Same as: MATSCI 175

MATSCI 171. Nanocharacterization Laboratory. 3-4 Units.
Students use optical microscopy, x-ray diffraction, scanning electron microscopy, x-ray photoelectron spectroscopy, atomic force microscopy and other techniques to characterize recently discovered perovskite semiconductors that can be used to make highly efficient solar cells. This course fulfills the Writing in the Major Requirement for MSE undergrads. Instruction on writing, statistics, generating effective plots with curve fits, using databases to find information and giving oral scientific presentations is given. Instruction on characterization techniques is provided, but it is expected that the students will have already taken a course like MATSCI 153 that covers the fundamentals of the techniques. The emphasis on this course is on doing nanocharacterization experiments and writing up the results. Undergraduates register for 161 for 4 units; graduates register for 171 for 3 units.
Same as: MATSCI 161

MATSCI 172. X-Ray Diffraction Laboratory. 3-4 Units.
Experimental x-ray diffraction techniques for microstructural analysis of materials, emphasizing powder and single-crystal techniques. Diffraction from epitaxial and polycrystalline thin films, multilayers, and amorphorous materials using medium and high resolution configurations. Determination of phase purity, crystallinity, relaxation, stress, and texture in the materials. Advanced experimental x-ray diffraction techniques: reciprocal lattice mapping, reflectivity, and grazing incidence diffraction. Enrollment limited to 20. Undergraduates register for 162 for 4 units; graduates register for 172 for 3 units.
Same as: MATSCI 162, PHOTON 172

MATSCI 173. Mechanical Behavior Laboratory. 3-4 Units.
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. Prerequisite: ENGR 50. Undergraduates register for 163 in 4 units; graduates register in 173 for 3 units.
Same as: MATSCI 163

MATSCI 174. Electronic and Photonic Materials and Devices Laboratory. 3-4 Units.
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. Prerequisite: 152 or 199 or consent of instructor. Undergraduates register in 164 for 4 units; graduates register in 174 for 3 units.
Same as: MATSCI 164

MATSCI 175. Nanoscale Materials Physics Computation Laboratory. 3-4 Units.
Computational exploration of fundamental topics in materials science using Java-based computation and visualization tools. Emphasis is on the atomic-scale origins of macroscopic materials phenomena. Simulation methods include molecular dynamics and Monte Carlo with applications in thermodynamics, kinetics, and topics in statistical mechanics. Required prerequisites: Freshman-level physics, undergraduate thermodynamics. Undergraduates register for 165 for 4 units; graduates register for 175 for 3 units.
Same as: MATSCI 165

MATSCI 190. Organic and Biological Materials. 3-4 Units.
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. Prerequisite: Thermodynamics and ENGR 50 or equivalent. Undergraduates register for 190 for 4 units; graduates register for 210 for 3 units.
Same as: MATSCI 210

MATSCI 192. Materials Chemistry. 3-4 Units.
An introduction to the fundamental physical chemical principles underlying materials properties. Beginning from basic quantum chemistry, students will learn how the electronic configuration of molecules and solids impacts their structure, stability/reactivity, and spectra. Topics for the course include molecular symmetry, molecular orbital theory, solid-state chemistry, coordination compounds, and nanomaterials chemistry. Using both classroom lectures and journal discussions, students will gain an understanding of and be well-positioned to contribute to the frontiers of materials chemistry, ranging from solar-fuel generation to next-generation cancer treatments. Undergraduates register in 192 for 4 units; graduates register in 202 for 3 units.
Same as: MATSCI 202

MATSCI 193. Atomic Arrangements in Solids. 3-4 Units.
Atomic arrangements in perfect and imperfect solids, especially important metals, ceramics, and semiconductors. Elements of formal crystallography, including development of point groups and space groups. Undergraduates register in 193 for 4 units; graduates register in 203 for 3 units.
Same as: MATSCI 203

MATSCI 194. Thermodynamics and Phase Equilibria. 3-4 Units.
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; thermodynamics of surfaces, elastic solids, dielectrics, and magnetic solids. Undergraduates register for 194 for 4 units; graduates register for 204 for 3 units.
Same as: MATSCI 204

MATSCI 195. Waves and Diffraction in Solids. 3-4 Units.
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. Undergraduates register for 195 for 4 units; graduates register for 205 for 3 units.
Same as: MATSCI 205, PHOTON 205

MATSCI 196. Defects in Crystalline Solids. 3-4 Units.
Thermodynamic and kinetic behaviors of 0-D (point), 1-D (line), and 2-D (interface and surface) defects in crystalline solids. Influences of these defects on the macroscopic ionic, electronic, and catalytic properties of materials, such as batteries, fuel cells, catalysts, and memory-storage devices. Prerequisite: 193/203. Undergraduates register for 196 for 4 units; graduates register for 206 for 3 units.
Same as: MATSCI 206

MATSCI 197. Rate Processes in Materials. 3-4 Units.
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. Undergraduates register for 197 for 4 units; graduates register for 207 for 3 units.
Same as: MATSCI 207

MATSCI 198. Mechanical Properties of Materials. 3-4 Units.
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. Undergraduates register for 198 for 4 units; graduates register for 208 for 3 units.
Same as: MATSCI 208

MATSCI 199. Electronic and Optical Properties of Solids. 3-4 Units.
The concepts of electronic energy bands and transports applied to metals, semiconductors, and insulators. The behavior of electronic and optical devices including p-n 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. Undergraduates register for 199 for 4 units; graduates register for 209 for 3 units.
Same as: MATSCI 209

MATSCI 200. Master's Research. 1-15 Unit.
Participation in a research project.

MATSCI 202. Materials Chemistry. 3-4 Units.
An introduction to the fundamental physical chemical principles underlying materials properties. Beginning from basic quantum chemistry, students will learn how the electronic configuration of molecules and solids impacts their structure, stability/reactivity, and spectra. Topics for the course include molecular symmetry, molecular orbital theory, solid-state chemistry, coordination compounds, and nanomaterials chemistry. Using both classroom lectures and journal discussions, students will gain an understanding of and be well-positioned to contribute to the frontiers of materials chemistry, ranging from solar-fuel generation to next-generation cancer treatments. Undergraduates register in 192 for 4 units; graduates register in 202 for 3 units.
Same as: MATSCI 192

MATSCI 203. Atomic Arrangements in Solids. 3-4 Units.
Atomic arrangements in perfect and imperfect solids, especially important metals, ceramics, and semiconductors. Elements of formal crystallography, including development of point groups and space groups. Undergraduates register in 193 for 4 units; graduates register in 203 for 3 units.
Same as: MATSCI 193

MATSCI 204. Thermodynamics and Phase Equilibria. 3-4 Units.
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; thermodynamics of surfaces, elastic solids, dielectrics, and magnetic solids. Undergraduates register for 194 for 4 units; graduates register for 204 for 3 units.
Same as: MATSCI 194

MATSCI 205. Waves and Diffraction in Solids. 3-4 Units.
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. Undergraduates register for 195 for 4 units; graduates register for 205 for 3 units.
Same as: MATSCI 195, PHOTON 205

MATSCI 206. Defects in Crystalline Solids. 3-4 Units.
Thermodynamic and kinetic behaviors of 0-D (point), 1-D (line), and 2-D (interface and surface) defects in crystalline solids. Influences of these defects on the macroscopic ionic, electronic, and catalytic properties of materials, such as batteries, fuel cells, catalysts, and memory-storage devices. Prerequisite: 193/203. Undergraduates register for 196 for 4 units; graduates register for 206 for 3 units.
Same as: MATSCI 196

MATSCI 207. Rate Processes in Materials. 3-4 Units.
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. Undergraduates register for 197 for 4 units; graduates register for 207 for 3 units.
Same as: MATSCI 197

MATSCI 208. Mechanical Properties of Materials. 3-4 Units.
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. Undergraduates register for 198 for 4 units; graduates register for 208 for 3 units.
Same as: MATSCI 198

MATSCI 209. Electronic and Optical Properties of Solids. 3-4 Units.
The concepts of electronic energy bands and transports applied to metals, semiconductors, and insulators. The behavior of electronic and optical devices including p-n 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. Undergraduates register for 199 for 4 units; graduates register for 209 for 3 units.
Same as: MATSCI 199

MATSCI 210. Organic and Biological Materials. 3-4 Units.
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. Prerequisite: Thermodynamics and ENGR 50 or equivalent. Undergraduates register for 190 for 4 units; graduates register for 210 for 3 units.
Same as: MATSCI 190

MATSCI 230. Materials Science Colloquium. 1 Unit.
May be repeated for credit.

MATSCI 251. Microstructure and Mechanical Properties. 3-4 Units.
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: MATSCI 163. Undergraduates register in 151 for 4 units; graduates register for 251 in 3 units.
Same as: MATSCI 151

MATSCI 256. Solar Cells, Fuel Cells, and Batteries: Materials for the Energy Solution. 3-4 Units.
Operating principles and applications of emerging technological solutions to the energy demands of the world. The scale of global energy usage and requirements for possible solutions. Basic physics and chemistry of solar cells, fuel cells, and batteries. Performance issues, including economics, from the ideal device to the installed system. The promise of materials research for providing next generation solutions. Undergraduates register in 156 for 4 units; graduates register in 256 for 3 units.
Same as: EE 293A, ENERGY 293A, MATSCI 156

MATSCI 299. Practical Training. 1 Unit.
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.

MATSCI 300. Ph.D. Research. 1-15 Unit.
Participation in a research project.

MATSCI 302. Solar Cells. 3 Units.
This course takes a comprehensive view of solar cells and what will need to be done to enable them to substantially change how the world obtains its electricity. After covering the fundamentals (light trapping, current flow in pn junctions, recombination) that are important for almost all photovoltaic technologies, the course will address technologies based on highly crystalline forms of silicon and gallium arsenide. The device simulator PC1D will be used to model solar cells. The course will then go through multijunctions cells with concentrators, low-cost thin-film solar cells, organic semiconductors, hybrid perovskites and nanowires. There will be discussions of module design and the economics of the solar industry. There will be a tour of a company that makes solar cells and guest lectures.

MATSCI 303. Principles, Materials and Devices of Batteries. 3 Units.
Thermodynamics and electrochemistry for batteries. Emphasis on lithium ion batteries, but also different types including lead acid, nickel metal hydride, metal air, sodium sulfur and redox flow. Battery electrode materials, electrolytes, separators, additives and electrode-electrolyte interface. Electrochemical techniques; advanced battery materials with nanotechnology; battery device structure. Prerequisites: undergraduate chemistry.

MATSCI 311. Lasers in Materials Processing. 3 Units.
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.

MATSCI 312. New Methods in Thin Film Synthesis. 3 Units.
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. SCPD offering.

MATSCI 316. Nanoscale Science, Engineering, and Technology. 3 Units.
This course covers important aspects of nanotechnology in nanomaterials synthesis and fabrication, novel property at the nanoscale, tools and applications: a variety of nanostructures including nanocrystal, nanowire, carbon nanotube, graphene, nanoporous material, block copolymer, and self-assembled monolayer; nanofabrication techniques developed over the past 20 years; thermodynamic, electronic and optical property; applications in solar cells, batteries, biosensors and electronics. Other nanotechnology topics may be explored through a group project. SCPD offering.

MATSCI 320. Nanocharacterization of Materials. 3 Units.
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.

MATSCI 321. Transmission Electron Microscopy. 3 Units.
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.

MATSCI 322. Transmission Electron Microscopy Laboratory. 3 Units.
Practical techniques in transmission electron microscopy (TEM): topics include microscope operation and alignment, diffraction modes and analysis, bright-field/dark-field imaging, high resolution and aberration corrected imaging, scanning TEM (STEM) imaging, x-ray energy dispersive spectrometry (EDS) and electron energy loss spectrometry (EELS) for compositional analysis and mapping. Prerequisite: 321, consent of instructor. Enrollment limited to 12.

MATSCI 323. Thin Film and Interface Microanalysis. 3 Units.
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. SCPD offering.

MATSCI 326. X-Ray Science and Techniques. 3 Units.
X-ray interaction with matter; diffraction from ordered and disordered materials; x-ray absorption, photoemission, and coherent scattering; x-ray microsocopy. Sources including synchrontrons, high harmonic generation, x-ray lasers. Time-resolved techniques and detector technology.
Same as: PHOTON 326

MATSCI 331. Atom-based computational methods for materials. 3 Units.
Introduction to atom-based computational methods for materials with emphasis on quantum methods. Topics include density functional theory, tight-binding and empirical approaches. Computation of optical, electronic, phonon properties. Bulk materials, interfaces, nanostructures. Molecular dynamics. Prerequisites - undergraduate quantum mechanics.

MATSCI 343. Organic Semiconductors for Electronics and Photonics. 3 Units.
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.

MATSCI 346. Nanophotonics. 3 Units.
Recent developments in micro- and nanophotonic materials and devices. Basic 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. Prerequisite: Electromagnetic theory at the level of 242.
Same as: EE 336

MATSCI 347. Introduction to Magnetism and Magnetic Nanostructures. 3 Units.
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.

MATSCI 353. Mechanical Properties of Thin Films. 3 Units.
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.

MATSCI 358. Fracture and Fatigue of Materials and Thin Film Structures. 3 Units.
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 cohesion and adhesion in bulk materials, composites, and thin film structures. Fracture mechanics approaches to toughening and subcritical crack-growth processes, with examples and applications involving cyclic fatigue and environmentally assisted subcritical crack growth. Prerequisite: 151/251, 198/208, or equivalent. SCPD offering.

MATSCI 359. Crystalline Anisotropy. 3 Units.
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.

MATSCI 380. Nano-Biotechnology. 3 Units.
Literature based. Principles that make nanoscale materials unique, applications to biology, and how biological systems can create nanomaterials. Molecular sensing, drug delivery, bio-inspired synthesis, self-assembling systems, and nanomaterial based therapies. Interactions at the nanoscale. Applications and opportunities for new technology.

MATSCI 381. Biomaterials in Regenerative Medicine. 3 Units.
Materials design and engineering 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. Prerequisites: undergraduate chemistry, and cell/molecular biology or biochemistry.
Same as: BIOE 361

MATSCI 382. Biochips and Medical Imaging. 3 Units.
The course covers state-of-the-art and emerging bio-sensors, bio-chips, imaging modalities, and nano-therapies which will be studied in the context of human physiology including the nervous system, circulatory system and immune system. Medical diagnostics will be divided into bio-chips (in-vitro diagnostics) and medical and molecular imaging (in-vivo imaging). In-depth discussion on cancer and cardiovascular diseases and the role of diagnostics and nano-therapies.
Same as: EE 225, SBIO 225

MATSCI 399. Graduate Independent Study. 1-10 Unit.
Under supervision of a faculty member.

MATSCI 400. Participation in Materials Science Teaching. 1-3 Unit.
May be repeated for credit.

MATSCI 801. TGR Project for MS Students. 0 Units.
.

MATSCI 802. TGR Dissertation for Ph.D Students. 0 Units.
.