MATERIALS SCIENCE AND ENGINEERING

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The Department of Materials Science and Engineering (MSE) is concerned with the relation between the structure and properties of materials, factors that control the internal structure of solids, and processes for altering the structure and properties of solids. It brings together in a unified discipline the developments in physical metallurgy, ceramics, and the physics and chemistry of solids. 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 MSE 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 newly renovated Jack A. McCullough building and the new 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 a number of 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 Research on Information Storage Materials (CRISM) 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, one with a number of desktop personal computers, and the other with five HP and DEC workstations. Both clusters are linked to the Internet.

Depending on the needs of their program, 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 an MSE 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 should apply for entrance after the beginning of the eighth quarter of undergraduate work and before the end of the eleventh quarter. The application must give evidence that the student possesses the potential for strong academic performance at the graduate level. Each application is evaluated by the department’s Admissions Committee. 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 Degree Progress in the Registrar’s Office, Old Union. Students entering the coterminal program and receiving both their B.S. and M.S. degree in Materials Science and Engineering should also see the “Master of Science for MSE Coterminal Students” section below.

GRADUATE PROGRAMS

Graduate students can specialize in any of the areas of materials science and engineering. Additional special programs are available in collaboration with other departments of the University.

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 (MSE) 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 students’ academic adviser, and submitted to the department’s Student Services Manager by the end of the first week of the students’ second quarter of study. Final changes to the master’s program must be submitted no later than one academic quarter prior to degree conferral.

Degree requirements (for students entering after September 1, 2001) are as follows:

1. A minimum of 33 units of MSE course work, including cross-listed courses, taken for a letter grade with these limitations:

a) A maximum of 9 units of cross-listed courses may be used in fulfilling this requirement.
b) One-unit seminars and research units cannot be used to fulfill this requirement.

2. Six courses selected from the core courses 201 through 210 or MSE 152 or 251. These core courses count towards the required 33 units of MSE course work, however:
   a) MSE 152 does not count for students with materials science undergraduate degrees.
   b) MSE 251 may not be used to fulfill this core requirement if the student has a materials science undergraduate degree, although it may be applied towards the required 33 units of MSE course work,
3. Lab courses MSE 171, 172, 173 (which count toward the required 33 units of MSE course work).

   Note: students who have had equivalent lab courses at other universities, equivalent practical experience, or have a materials related degree or background 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. Twelve units of approved course electives that result in a technically coherent program. Of the 12 units of elective courses:
   a) Nine of the 12 units must be taken for a letter grade.
   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 9 units of MSE research units may be counted. MS research units may only be counted if writing an MS 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 12 units total
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 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 submit a program of study that includes 6 to 9 MSE research units to the department for approval at the end of the first week of the second quarter of their program.

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. Three copies of the report (one copy for each approving faculty member and the department library), 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 the department faculty an ability to conduct and report directed research. Refer to the *Materials Science and Engineering Student Handbook* for more information and further clarification concerning this report.

In cases where students decide to pursue research after the initial program submission deadline, they should submit a revised MS Program Proposal at least two quarters before the degree is granted. The total combined units of MSE research units, seminars, language courses, and undergraduate courses cannot exceed 12. If a master's research report is not to be submitted, units of MSE 200 *cannot* be applied to the department's requirement of 45 units for the master's degree.

M.S. FOR MSE COTERMINAL STUDENTS

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 (MSE) requires a minimum of 45 units for a master's degree. Students who have received or are currently working towards a B.S. degree in Materials Science and Engineering from Stanford and are pursuing an M.S. in Materials Science and Engineering should follow the requirements below in lieu of those stated in the "Master of Science" section listed above. Master's Program Proposal forms should be completed, signed by the students' academic adviser, and submitted to the department's Student Services Manager by the end of the first week of the students' second quarter of study. Final changes to the master's program must be submitted *no later* than one academic quarter prior to degree conferral.

Degree requirements (for students who entered after September 1, 2001) are as follows:

1. Three of the remaining core classes, MSE 201-210.
2. Twelve units of non-cross-listed MSE 300-level courses (not including MSE 300 Ph.D. research).
3. Twenty-four units of approved elective courses that constitute a technically coherent program. Of the 24 units of elective courses:
   a) Twenty-one of the 24 units must be taken for a letter grade.
   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 9 units of M.S. research units (MSE 200) may be used.*
   d) A maximum of 6 units may be undergraduate units.
   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 it is not English).
   f) The combination of seminar, undergraduate, and language units may not exceed 9 units total.
   g) The combination of research, seminar, undergraduate, and language units may not exceed 15 units total.
3. A minimum grade point average (GPA) of 2.75 for degree course work at Stanford.

* See the Master's Research Report above for information on Research Report requirements.

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

When a student is admitted to the graduate program, he or she is admitted specifically into either the M.S. or 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 can 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, and two letters of recommendation from members of the Stanford faculty, including one from the student's prospective adviser and at least one from an MSE 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. The Admissions Committee and the department chair consider the student's original application to the graduate program as well as the material provided with the transfer petition. Decisions regarding these petitions are normally available by the fourth week of Spring Quarter.

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 substantial equivalent requirements of the M.S. in Materials Science and Engineering, and must file a petition requesting admission to the program, as well as stating the type of research to be done and the professor who will be supervising. 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 should include 9 units of graduate non-cross-listed courses in materials science (exclusive of research units, seminars, colloquia, MSE 400 Participation in Teaching, and so on) beyond the requirements for the M.S. degree, and additional research or other units to meet the 45-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 (for students entering after September 1, 2001) 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) 33 units must be taken as non-cross-listed MSE courses for a letter grade.
   b) All students must take six core courses.*
      1) 203, 204 and 207 are required of all students in their first year.
      2) All students must take three additional core courses in their first year as follows: either 205 or 206; and two of 208, 209, or 210.
   c) A minimum of 12 units of 300-level courses from the MSE faculty (not including MSE 300, Ph.D. research).
   d) A minimum of 12 units of courses taken from one of the following lists of Advanced Specialty Courses (see below). Some and/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.
   e) The remaining units beyond the 57 units of technical course work may consist of Ph.D. research, seminars, teaching experience, and so on.
2. First-year Ph.D. students are required to take the MSE Colloquium, MSE 230 each quarter of their first year.
3. Pass a departmental oral qualifying examination by the end of January of their second year. A grade point average (GPA) of 3.25 from the six core classes taken (201-210) is required for admission to the Ph.D. qualifying exam. Students whose GPA is between 3.00 and 3.25 may petition for possible admission to the 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.
4. Maintain a GPA of 3.0 in all degree courses taken at Stanford.
5. Present the result of the dissertation at a department seminar immediately preceding 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 MSE from another university may request to transfer up to 45 units of equivalent work toward the total of 135 required units.

ADVANCED SPECIALTY COURSES

Biomaterials: App. Phys. 192; Biophys. 228; Chem. Engr. 260, 310A,B, 350, 355, 440, 444A, 452; Mech. Engr. 182, 257, 281, 284A,B, 285, 286

Electronic Materials Processing: Elect. Engr. 212, 216, 217, 311, 316, 357, 410; MSE 312

Materials Characterization: App. Phys. 216, 218; Chem. Engr. 345; Elect. Engr. 329; MSE 320, 321, 322, 323, 324, 325

Mechanical Behavior of Solids: Aero. & Astro. 252, 256; MSE 251, 255, 260, 270, 350, 351, 352, 353, 354A,B, 355, 356, 358, 359; Mech. Engr. 235A,B,C, 238A,B

Physics of Solids and Computation: App. Phys. 218, 272, 273, 372, 373; Chem. Engr. 444A; Elect. Engr. 222, 223, 228, 327, 328, 329; MSE 330, 343, 347, 348, 349, 359; Mech. Engr. 244, 249B

Soft Materials: Chem. Engr. 260, 310A,B, 460, 462; MSE 343

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.

COURSES

(WIM) indicates that the course meets the Writing in the Major requirements.

(AU) indicates that the course is subject to the University Activity Unit limitations (8 units maximum).

PRIMARILY FOR UNDERGRADUATES

50. Introductory Science of Materials—(Enroll in Engineering 50.)
4 units, Win (Bravman)
Spr (Sinclair)

100. Undergraduate Independent Study—Independent study in materials science under supervision of a faculty member.
1-3 units, any quarter (Staff)

150. Undergraduate Research—Participation in a research project.
3-6 units, any quarter (Staff)

151. Microstructure and Mechanical Properties—For undergraduates; see 251. Prerequisite: Engineering 50 or equivalent.
3 units, Aut (Dauskardt)

152. Electronic Materials Engineering—Materials science and engineering for information technology 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.
3 units, Spr (McIntyre)

159Q. Stanford Introductory Seminar: Research in Japanese Companies—Preference to sophomores. The home-campus equivalent of the course taught at Kyoto. Knowledge from this research, and company visits, is evaluated in a seminar/discussion setting. Lecture/discussion on the structure of a Japanese company from the point-of-view of Japanese society. Visiting researchers from Japanese companies, with brief presentations and extensive question and answer periods, explore the Japanese research ethic.
3 units, Spr (Sinclair)

161. Materials Science Lab I—For undergraduates. The development of standard lab procedures for materials scientists with an emphasis on microscopy, metallography, and technical writing. Techniques: optical,

scanning-electron, atomic-force microscopy, and metallographic specimen preparation. The relationships between microscopic observation, material properties, and processing. (WIM)
4 units, Aut (Doan)

162. Materials Science Lab II—For undergraduates. 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.
4 units, Win (Staff)

163. Materials Science Lab III—For undergraduates. Lab on experimental techniques for the study of the mechanical properties of materials, including fracture toughness testing of metallic materials, ductile-to-brittle transition curves, fracture of ceramics using indentation techniques, and effects of grain size on yielding and strain hardening. Prerequisites: 198/208, 151/251, or equivalent.
4 units, Spr (Nix)

167. Sports Materials Laboratory Project—For undergraduates. The Sports Materials Laboratory is an industry-supported research program allowing students to examine real-world materials design issues under the guidance of both industry and University mentors. Includes modeling and experimental work in a variety of metal, polymer, ceramic, and composite systems. Addresses fundamental and applied materials issues including materials characterization, microstructure-property relationships, materials and component design, and test system design. Research projects are expected to be completed in one academic year. Enrollment limited to number of projects available. Consent of instructor required. May be repeated for credit.
1-3 units, Aut, Win, Spr (Staff)

168. Sports Materials Laboratory Seminar—For undergraduates. Weekly discussions and research presentations for the Sports Materials Laboratory. Concurrent participation in a Sports Materials Laboratory project required. May be repeated for credit.
1 units, Aut, Win, Spr (Staff)

169Q. Stanford Introductory Seminar: Issues in Science and Christianity—Preference to sophomores. Insights as provided by modern science and the Christian perspective, and ways to integrate them. Seven patterns that have been used in the effort to describe the interaction between them. Contemporary issues, e.g., creationism vs. evolution, determinism vs. free will, issues at the beginning and ending of life, and responsibility for the environment.
3 units, Win (Bube)

170. Materials Selection in Design—For undergraduates; see 270. Prerequisites: Engineering 14 and 50 or Mechanical Engineering 111.
3 units, Win (Prinz) alternate years, not given 2002-03

171. Materials Science Lab I—For graduates; see 161. Prerequisite: Engineering 50 or equivalent.
3 units, Aut (Doan)

172. Materials Science Lab II—For graduates; see 162. Prerequisite: 193/203.
3 units, Win (Staff)

173. Materials Science Lab III—For graduates; see 163. Prerequisites: 198/208, 151/251, or equivalent.
3 units, Spr (Nix)

177. Sports Materials Laboratory Project—For graduates; see 167.
1-3 units, Aut, Win, Spr (Staff)

178. Sports Materials Laboratory Seminar—For graduates; see 168.
1-3 units, Aut, Win, Spr (Staff)

179Q. Stanford Introductory Seminar: Materials in Sports—Preference to sophomores. Introduction to materials science using sporting equipment as a vehicle to highlight material properties, performance, and selection criteria. The classes of material, and the properties relevant to sporting equipment performance. Examples from modern sporting equipment (golf clubs, tennis rackets, skis, and bicycles) highlight the relationship between material properties and product performance.
3 units, Aut (Clemens)

190. Organic Materials—For undergraduates; see 210.
4 units, Aut (McGehee)

191. Mathematical Methods for Solid State Materials Science—For undergraduates; see 201. Prerequisite: familiarity with ordinary differential equations.
4 units, Aut (Barnett)

192. Solid State Thermodynamics—For undergraduates; see 202. Prerequisite: physical chemistry or introductory thermodynamics.
4 units, Aut (Musgrave)

193. Atomic Arrangements in Solids—For undergraduates; see 203.
4 units, Aut (Bravman)

194. Phase Equilibria and Thermodynamics—For undergraduates; see 204. Prerequisite: 192/202.
4 units, Win (McIntyre)

195. Waves and Diffraction in Solids—For undergraduates; see 205. Prerequisite: 193/203 or consent of instructor.
4 units, Win (Clemens)

196. Imperfections in Crystalline Solids—For undergraduates; see 206. Prerequisite: 193/203.
4 units, Win (Nix)

197. Rate Processes in Materials—For undergraduates; see 207. Prerequisites: 191/201, 192/202, 194/204.
4 units, Spr (Clemens)

198. Mechanical Properties of Materials—For undergraduates; see 208. Prerequisites: 193/203, 196/206.
4 units, Spr (Dauskardt)

199. Electrical and Magnetic Properties of Solids—For undergraduates; see 209. Prerequisite: 195/205 or equivalent.
4 units, Spr (Wang)

PRIMARILY FOR GRADUATES

200. Master's Research—Participation in a research project.
1-9 units, any quarter (Staff)

201. Mathematical Methods for Solid State Materials Science—Introduction to mathematical techniques useful in the study of solid state physics and materials science; recommended for graduate students who intend to pursue the solid state physics track in MSE and who did not study this material as an undergraduate. Emphasis is on mathematic techniques with example problems from solid state science. Topics: the reciprocal lattice, matrix methods, vibrations of monatomic and diatomic lattices, solution of Schrodinger's equation (including the hydrogen atom, the free particle in a box, the harmonic oscillator, tunneling, and Kronig-Penney model with energy bands). Possibly also variational and/or perturbation methods with applications to thermodynamics and quantum mechanics.
3 units, Aut (Barnett)

202. Solid State Thermodynamics—The principles of thermodynamics and relationships between thermodynamic variables. Equilibrium in thermodynamic systems. Elementary statistical thermodynamics. Ther-

modynamics of multicomponent systems, interfaces, and defects in solids. Prerequisite: physical chemistry or introductory thermodynamics.
3 units, Aut (Musgrave)

203. Atomic Arrangements in Solids—Atomic arrangements in perfect and imperfect crystalline solids, defect chemistry, and elements of formal crystallography, including development of point groups and space groups.
3 units, Aut (Bravman)

204. Phase Equilibria and Thermodynamics—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; statistical models of alloy thermodynamics; binary and ternary phase diagram construction; thermodynamics of surfaces.
3 units, Win (McIntyre)

205. Waves and Diffraction in Solids—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)

206. Imperfections in Crystalline Solids—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. Introduction to the structure and properties of interfaces in solids. Prerequisite: 193/203.
3 units, Win (Nix)

207. Rate Processes in Materials—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: 191/201, 192/202, 194/204.
3 units, Spr (Clemens)

208. Mechanical Properties of Materials—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, 196/206.
3 units, Spr (Dauskardt)

209. Electrical and Magnetic Properties of Solids—Introduction to the electronic, magnetic, and optical properties of solids. Emphasis is on concepts and models of phonons and electronic energy bands as applied to metals, semiconductors, magnetic materials, and insulators. Elementary quantum and statistical mechanics concepts are utilized. Prerequisite: 195/205 or equivalent.
3 units, Spr (Wang)

210. Organic Materials—Bonding and intermolecular interactions in organic materials. The fundamentals of synthesizing and processing polymers, block copolymers, and other macromolecular materials. Introduction to structure and properties of polymers, colloids, amphiphilic molecules, liquid crystals, and biomaterials.
3 units, Aut (McGehee)

227. Scattering Physics—(Enroll in Applied Physics 196.)
4 units, Spr (Greven)

230. Materials Science Colloquium—Can be repeated for credit. (AU)
1 unit, Aut (Nix, McIntyre)
Win (Dauskardt, McGehee)
Spr (Wang, Barnett)

251. Microstructure and Mechanical Properties—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: Engineering 50 or equivalent.
3 units, Aut (Dauskardt)

255. Mechanical Properties of Composites—Introduction to composite materials and their applications. Elastic and plastic properties of structural polymers, metals, and ceramics, reinforced by fibers, laminates and dispersed particles. Application of micromechanics to the understanding of strength, fracture toughness, creep resistance, and thermal properties of composites. Synthesis, processing, and the characterization of structural composites.
3 units, Aut (Nix) alternate years, not given 2002-03

270. Materials Selection in Design—Methods to select materials for engineering applications, emphasizing structural and thermal properties. Fundamentals of the interrelation between material 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: Engineering 14 and 50 or Mechanical Engineering 111.
3 unit, Win (Prinz) alternate years, not given 2002-03

299. Practical Training—Provides 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, any quarter (Staff)

300. Ph.D. Research—Participation in a research project.
1-15 units, any quarter (Staff)

310. Integrated Circuit Fabrication Processes—(Enroll in Electrical Engineering 212.)
3 units, Aut (Plummer)

312. New Methods in Thin Film Synthesis—Techniques to grow thin films on an atomic scale provide the materials base for new classes of coatings and devices. The fundamentals of vacuum growth techniques, molecular beam epitaxy (MBE), chemical vapor deposition (CVD), ion beam assisted deposition, and plasma processes. Relationships between deposition parameters and film properties. Industrial applications of thin film synthesis.
3 units, Aut (Wang)

315. Polymer Surfaces and Interfaces—(Enroll in Chemical Engineering 460.)
3 units (Frank) alternate years, given 2002-03

316. Nanoscale Science, Engineering, and Technology—The techniques for patterning materials at the nanometer length scale: self-assembly, electron beam lithography, scanning probe lithography, and epitaxy. Electrical, optical, magnetic, chemical, and mechanical properties of nanostructured inorganic/organic hybrids, synthetic and biological supramolecules (e.g., dendrimers, liquid crystals, proteins, DNA), epitaxially grown films, nanoparticles, nanotubes, nanowires, self-assembled monolayers, and molecular wires. The hierarchical design of materials, molecular electronics, biomimetics, and scanning probe microscopy.
3 units, Win (McGehee)

317. Advanced Integrated Circuit Fabrication—(Enroll in Electrical Engineering 311.)
3 units, Spr (Saraswat)

318. Integrated Circuit Fabrication Laboratory—(Enroll in Electrical Engineering 410.)
3-4 units, Win (Saraswat)

319. Electron and Ion Beams for Semiconductor Processing—(Enroll in Electrical Engineering 217.)
3 units, alternate years, given 2002-03

320. Techniques for Microstructural Characterization of Materials—Current methods of directly examining the microstructure of materials. Topics: optical microscopy, scanning electron microscopy, field ion microscopy, transmission electron microscopy, x-ray topography, and scanning transmission electron microscopy. Emphasis is on the electron-optical techniques. Prerequisite: 193/203.
3 units, Win (Sinclair) alternate years, not given 2002-03

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. Prerequisite: 193/203, 195/205, or equivalent.
3 units (Sinclair) alternate years, given 2002-03

322. Transmission Electron Microscopy Laboratory—Experimental application of electron microscopy to typical problems in materials science, including specimen preparation, microscope operation and alignment, recording and analysis of bright and dark field images and diffraction patterns, dislocation and stacking fault characteristics, analytical and high resolution techniques. Prerequisite: 321, consent of instructor.
3 units, Spr (Marshall)

323. Thin Film and Interface Microanalysis—The science and technology of a variety 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.
3 units, Win (Kelly) alternate years, not given 2002-03

324. Selected Topics in Thin Film Microcharacterization—Case study characterizing materials, defining problems in characterizing surfaces or thin films, carrying out analyses of relevant samples, and reporting the results. Students operate modern electron, ion, and x-ray probe instruments to study samples. Methodology for approaching characterization problems; experience in interpreting and presenting experimental results. Emphasis is on the application of theoretical measurement capabilities to practical problems, and the capabilities and limitations of modern techniques. Topics: choosing the appropriate techniques, analytical pitfalls, quantitative analysis, effects of noise and other uncertainties on analytical precision. Enrollment limited. Prerequisite: 323 or consent of instructor.
3 units (Kelly) alternate years, given 2002-03

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) alternate years, not given 2002-03

327. Scattering Physics—(Enroll in Applied Physics 218.)
3 units, Spr (Greven)

330. Ceramics for Electronic Applications—Electronic and ionic conduction, dielectric, piezoelectric, and opto-electronic properties of advanced ceramic materials. Behavior of bulk polycrystalline ceramics and thin films. The relationships among processing history, microstructure, point defect chemistry, and the functional properties of ceramic. Application areas: high permittivity on-chip capacitor dielectrics, piezoelectric sensors/actuators, fast ion conductors, electrical and thermal transducers, and electro-optic devices. Prerequisite: 209 or equivalent.
3 units, Aut (McIntyre) alternate years, not given 2002-03

331. Solid State Physics I—(Enroll in Applied Physics 272.)
3 units, Win (Manoharan)

332. Solid State Physics II—(Enroll in Applied Physics 273.)
3 units, Spr (Manoharan)

334. Basic Physics for Solid State Electronics—(Enroll in Electrical Engineering 228.)
3 units, Aut (Fan)

335. Properties of Semiconductor Materials—(Enroll in Electrical Engineering 327.)
3 units, alternate years, given 2002-03

336. Physics of Advanced Semiconductor Devices—(Enroll in Electrical Engineering 328.)
3 units, Spr (J. Harris) alternate years, not given 2002-03

341. Principles and Models of Semiconductor Devices—(Enroll in Electrical Engineering 216.)
3 units, Aut (Harris)

342. The Electronic Structure of Surfaces and Interfaces—(Enroll in Electrical Engineering 329.)
3 units, alternate years, given 2002-03

343. Organic Materials for Electronic and Photonic Devices—Effects of chemical design and processing on the structure and properties of electrically and optically active organic materials. Emphasis is on explaining the electronic band structure, conductivity, non-linear optical activity, and luminescence efficiency of organic semiconductors. Design, fabrication, and performance of organic light-emitting diodes, lasers, field-effect transistors, photovoltaic cells, photodetectors, optical switches, and photorefractive films. Liquid-crystalline-based devices, photonic crystals, and the use of soft lithography, printing, and self assembly to pattern integrated circuits.
3 units, Spr (McGehee)

344. Solid-State Sensors and Actuators—(Enroll in Electrical Engineering 312.)
3 units, Win (Kovacs)

345. Advanced VLSI Devices—(Enroll in Electrical Engineering 316.)
3 units, Win (Saraswat)

347. Introduction to Magnetism and Magnetic Materials—Atomic origins of magnetic moments. Magnetic exchange and ferromagnetism. Types of magnetic order. Magnetic anisotropy. Domains, domain walls, and their origin. Hysterisis loops and their relationship to fundamental physical properties. Hard and soft magnetic materials. Demagnetization factors. Applications of magnetic materials, especially to information storage. Prerequisites: Physics 53 and 57, or equivalents.
3 units, not given 2001-02

349. Introduction to Information Storage Systems—(Enroll in Electrical Engineering 335.)
3 units, Win (Wang)

350. Micromechanics—Use of the theory of elasticity to discuss fields of dislocations, inclusions, inhomogeneities, and their interactions in deformable solids. Applications to the microscopic foundations of macroscopic plasticity, the effects of strain energy on morphologies associated with phase transformations, and the determination of "effective" properties of composite media. Prerequisite: any brief introduction to the theory of elasticity, or consent of instructor.
3 units (Barnett) not given 2001-02

352. Stress Analysis of 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, some familiarity with matrix algebra.
3 units (Barnett) alternate years, given 2002-03

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) alternate years, not given 2002-03

354A. Theory and Applications of Elasticity—(Enroll in Mechanical Engineering 240A.)
3 units, Win (Barnett)

354B. Introduction to Fracture Mechanics—(Enroll in Mechanical Engineering 240B.)
3 units (Gao) not given 2001-02

355. Time-Dependent Plasticity—Theories and mechanisms of creep. Temperature and strain rate effects on the plastic flow of solids. The relation of high temperature strength and ductility of materials to structure. Prerequisite: 198/208.
3 units (Nix) alternate years, given 2002-03

356. Fatigue Design and Analysis—(Enroll in Mechanical Engineering 245.)
3 units, Win (Nelson)

357. Physical Solid Mechanics—(Enroll in Mechanical Engineering 229.)
3 units (Cho) not given 2001-02

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. Prerequisite: 151/251, 198/208, or equivalent.
3 units, Win (Dauskardt)

359. Crystalline Anisotropy—Introductory matrix and tensor analysis with applications to the effects of crystal symmetry on elastic deformation, thermal expansion, diffusion, piezoelectricity, magnetostriction, and thermodynamics, following a treatment at the level of Nye's text. Homework sets use Mathematica.™
3 units (Barnett) not given 2001-02

360. Techniques of Failure Analysis—(Enroll in Aeronautics and Astronautics 252.)
2 units, Spr (Ross)

361. Mechanics of Composites—(Enroll in Aeronautics and Astronautics 256.)
3 units, Win (Chang)

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

405. Seminar in Applications of Transmission Electron Microscopy—Can be repeated for credit. (AU)
1 unit, Win, Spr (Sinclair)

459. Frontiers in Interdisciplinary Biosciences—(Cross-listed in multiple departments in the schools of Humanities and Sciences, Engineering, and Medicine; students should enroll directly through their affiliated department if listed, otherwise enroll in ChE 459.) An introduction to cutting-edge research involving interdisciplinary approaches to bioscience and biotechnology; for specialists and non-specialists. Organized and sponsored by the Stanford BioX Program. Three seminars each quarter address a broad set of scientific and technical themes related to interdisciplinary approaches to important issues in bioengineering, medicine, and the chemical, physical, and biological sciences. Leading investigators from Stanford and throughout the world present the latest breakthroughs and endeavors that cut broadly across many core disciplines. Pre-seminars introduce basic concepts and provide background for non-experts. Registered students attend all pre-seminars in advance of the primary seminars, others welcome. Prerequisite: keen interest in all of science, engineering, and medicine with particular interest in life itself. Recommended: basic knowledge of mathematics, biology, chemistry, and physics.
1 unit, Aut, Win, Spr (Robertson)

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