Materials Science and Engineering Program

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Associate Professors

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Richard K. Herz, Ph.D., *MAE*
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Assistant Professors

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Materials Science and Engineering Program is concerned with the study of the structure and properties of materials. The Materials Science and Engineering Program at UCSD aims to provide fundamental knowledge for quantitative understanding of materials with the objective of predicting, modifying, and tailoring the properties of materials to yield, at the technology level, enhanced material performance. The foundations of materials science are the basic sciences of physics, chemistry, and mathematics. The great variety of materials response, at the optical, magnetic, electrical, mechanical, and chemical levels, requires a solid scientific foundation and breadth of basic knowledge from the materials scientists. The interdisciplinary nature of the program at UCSD is ideally suited to address this requirement. The graduate of the Materials Science and Engineering Program benefits from unique research facilities existing at UCSD. These include the resources in the Departments of MAE, SE, ECE, Physics, Chemistry/Biochemistry, Bioengineering, and SIO, as well as in the Center of Excellence for Advanced Materials and the Center for Magnetic Recording Research. Of particular emphasis within the program is the experimental investigation and theoretical modeling of the mechanical response and failure models of advanced materials at ultra-high strain rates; electronic, superconducting, magnetic, and optical properties of materials for advanced applications; biomaterials; and advanced composite materials for civil structures.

The Graduate Program

The Materials Science and Engineering Program is interdisciplinary, with participation of faculty members from several departments. Faculty from the following departments participate in the Materials Science and Engineering Graduate Program: the Departments of Mechanical and Aerospace Engineering (MAE), Structural Engineering (SE), Bioengineering, Physics, Scripps Institution of Oceanography (SIO), Electrical and Computer Engineering (ECE), and Chemistry. The governance of the program is carried out by the executive committee of the program. The executive committee coordinates all affairs of the Materials Science and Engineering Program, including student admissions, degree requirements, graduate courses in materials science given by various participating departments, maintenance of laboratory instructional facilities, seminars, special courses, part-time instructors, and related matters.

Undergraduate preparation for the materials science and engineering M.S. and Ph.D. normally would include a degree in materials science and in engineering or physical sciences, such as physics, chemistry, geology, and related disciplines. Students are expected to have an adequate mathematics, physics, chemistry, and related basic sciences background.

Master's Degree Program

The program offers the M.S. degree in materials science and engineering under both the Thesis Plan I and the Comprehensive Examination Plan II; see "Graduate Studies: Master's Degree." The requirements for the M.S. degree are as follows:

1. All students must complete a total of thirty-six units.
2. All students must complete a core of the following six courses:

   (1)MS 227; (2)MS 201A; (3)MS 201B; (4)MS 201C; (5)MS 205A; (6)Physics 152A.

   (Physics 211A can replace 152A with adviser's permission.) See "Courses" for descriptions.
3. Students may include up to twelve units of undergraduate courses. These include the one undergraduate core course, Physics 152A.
4. Enroll in MATS200, as required. See "Courses" for descriptions.
5. Remaining courses to complete the thirty-six unit requirement for the M.S. degree may be selected from an approved list of graduate courses with the consent of a faculty adviser.
6. Students either complete a thesis (Plan I) or pass a comprehensive examination (Plan II) as described in the "Graduate Studies" section of this catalog.

7. Students must meet all other requirements established by the university.

Students who transfer with some graduate credit or an M.S. from another institution will have their records reviewed by a faculty adviser, and an appropriate individual course of study may be approved.

The Ph.D. Program

After completing the M.S. degree (or meeting equivalent requirements) and meeting the minimum standard on the comprehensive examination to be admitted to or continue in the Ph.D. program, a student must:

1. Meet all the university's residency and other requirements.
2. Successfully complete three advanced graduate courses (in addition to those required for the M.S. degree) which have been approved by the student's potential dissertation adviser.
3. Enroll in MATS200, as required. See "Courses" for descriptions.
4. Pass the Literature Review Examination. This requirement must be successfully completed within one year after passing the Comprehensive Examination.
5. Pass the Ph.D. Qualifying Examination (Senate Exam) to be advanced to Ph.D. candidacy.
6. Successfully complete and defend a dissertation which, in the opinion of the dissertation committee, contains original work that should lead to publication of at least one significant article in an appropriate refereed journal.

In principle, it should be possible to finish the M.S. degree in three quarters, and a Ph.D. in an additional three years. Ph.D. time limits are as follows: Pre-candidacy—four years; Support limit—six years; Total time limit—seven years; Normative time limit for a properly prepared B.S. student—five years. (See "Graduate Studies–Ph.D. Time Limits" for further explanation.)

Departmental Examination

THE COMPREHENSIVE EXAMINATION

The examination will consist of twelve questions, two from each of the six core courses. A passing grade is 60 percent for the Master's degree, and 70 percent for the Ph.D. The examination will not exceed six hours in duration. The examination is usually administered the second week in January, and a week after spring quarter finals week in June. Typically, students take the exam after one year of full-time enrollment. This exam may only be retaken once before the end of the second year of study.

THE LITERATURE REVIEW EXAMINATION

The Literature Review Examination tests the student's ability to prepare and present a comprehensive overview of a topic based on existing journal literature. It should be a comprehensive discussion of the literature, scientific theory, problems or theoretical deficiencies, and possible areas of research in some area of materials science and engineering. The topic may be in the general area in which the student plans to pursue his or her thesis research, or it may be in an unrelated field. The topic must be approved by the three faculty member committee in advance of the seminar. The Literature Review Examination is not to be a discussion of the student's research project or their research proposal. A presentation which includes the student's own work which has not been published will constitute a no pass grade. This exam must occur within one year of the student having passed the Comprehensive Examination.

COURSES

GRADUATE

200. Graduate Seminar (0)
Each graduate student in the Materials Science and Engineering Program is expected to attend a weekly seminar in materials science or related areas. M.S. students must enroll for three quarters, Ph.D. students for six quarters, as of fall 1995. (S/U grades only.) (F,W,S)

201A. Thermodynamics of Solids (4)
The thermodynamics and statistical mechanics of solids. Basic concepts; equilibrium properties of alloy systems; thermodynamic information from phase diagrams, surfaces, and interfaces; crystalline defects. *Prerequisite: consent of instructor.*

201B. Solid State Diffusion and Reaction Kinetics (4)
Thermally activated processes, Boltzmann factor, homogeneous and heterogeneous reactions, solid state diffusion, Fick's laws, diffusion mechanisms, Kirkendall effect, Boltzman-Matano analysis, high diffusivity paths. *Prerequisite: consent of instructor.*

201C. Phase Transformations (4)
Classification of phase transformations: displacive and reconstructive transformations: classical and nonclassical theories of nucleation: Becker-Doering, Volmer-Weber, lattice instabilities, spinodal decomposition. Growth theories: interface migration, stress effects, terrace-ledge mechanisms, epitaxial growth, kinetics, and mechanics. Precipitation. Order-disorder transformations. Solidification. Amorphization. *Prerequisite: consent of instructor.*

205A. Imperfections in Solids (4)
Point, line, and planar defects in crystalline solids, including vacancies, self-interstitials, solute atoms, dislocations, stacking faults, and grain boundaries; effects of imperfections on mechanical properties; interactions of dislocations with point defects; strain hardening by micro-obstacles, precipitation, and alloying elements. *Prerequisite: consent of instructor.*

205B. Advanced Study of Defects in Solids (4)
Advanced topics in dislocation theory and dislocation dynamics. Defects and defects interactions. Atomistic and subatomistic effects. Physical models based on microscopic considerations. *Prerequisite: MS 205A or consent of instructor.*

207. Surface Reactions, Corrosion, and Oxidation (4)
The nature of surfaces; nucleation and growth of surface films. Techniques for studies of surface structures and of surface films. Types of corrosion phenomena and mechanisms of corrosion. Methods of corrosion control and prevention. Mechanisms of oxidation. Control of oxidation by alloying and surface coatings. *Prerequisite: MS 201A or consent of instructor.*

211A. Mechanical Properties (4)
Review of basic concepts in mechanics of deformation; elasticity, plasticity, viscoelasticity, and creep; effects of temperature and strain-rate on inelastic flow; microstructure and mechanical properties; application of basic concepts to selected advanced materials. *Prerequisite: consent of instructor.*

211B. Advanced Mechanical Behavior (4)
Rate mechamisms in crystalline solids. Kinetics and dynamics of plastic flow by slip at low and high strain rates. Mechanisms of inelasticity in nonmetals, metals, and polymeric materials. Mechanisms of failure and effects of strain rates. *Prerequisite: MS 211A or consent of instructor.*

213A. Dynamic Behavior of Materials I (4)
Elastic waves in continuum; longitudinal and shear waves. Surface waves. Plastic waves; shock waves; Rankine-Hugoniot relations. Method of characteristics, differential and difference form of conservation equations; dynamic plasticity and dynamic fracture. Shock wave reflection and interaction. *Prerequisite: consent of instructor.* (F)

213B. Dynamic Behavior of Materials II (4)
Shock induced phase transformations and reactions. Wave propagation through distended materials. Impact; Mie-Gruneisen and other equations of state, the Gurney equation. Detonation theory. Dislocation behavior at high strain rates. Shear instabilities. Spalling and fragmentation. *Prerequisite: consent of instructor.* (W)

218. Fatigue, Fracture, and Failure Analysis in Engineering Materials (4)
The course will cover the engineering and scientific aspects of fatigue crack initiation, stable crack growth, fatigue life predictions, selection of materials for fatigue applications, fractography, and failure analysis, includ-

ing case studies. *Prerequisites: MAE 160 or equivalent and consent of instructor.*

225. Materials for Magnetic Recording (4)
Properties of magnetic materials utilized as magnetic recording media and heads: magnetic structure of oxides and metals; fine particle magnetism; micromagnetic analysis; hysteresis and reversal mechanisms of hard materials; dynamic processes and domain patterns of soft materials; thermal fluctuations; multilayer phenomena; giant magnetoresistance. *Prerequisites: undergraduate electromagnetism and solid state physics or consent of instructor.*

227. Structure and Bonding of Solids (4)
Key concepts in the atomic structure and bonding of solids such as metals, ceramics, and semiconductors. Symmetry operations, point groups, lattice types, space groups, simple and complex inorganic compounds, structure/property comparisons, structure determination with X-ray diffraction. Ionic, covalent, metallic bonding compared with physical properties. Atomic and molecular orbitals, bands verses bonds, free electron theory. *Prerequisite: graduate student or consent of instructor.*

230. Electrochemistry (4)
Application of electrochemical techniques to chemistry research. Basic electrochemical theory and instrumentation: the diffusion equations, controlled potential, and current methods. Electro-chemical kinetics, Butler-Volmer, Marcus-Hush theories, preparative electro-chemistry, analytical electrochemistry, solid and polymer electrolytes, semiconductor photo-electrochemistry.

233A-B. Processing and Synthesis of Advanced Materials (4-4)
Background information on conventional techniques: forging, rolling, drawing, casting. Rapid solidification processing of metals and ceramics. Production of composites. Directionally solidified eutectics. Combustion synthesis. Sol-gel synthesis of ceramics. Mechanical alloying. Shockwave synthesis and processing. Thin film techniques. Laser glazing. Electron beam mixing. Molecular beam epitaxy. Superplastic processing. *Prerequisite: consent of instructor.*

236. Ceramic and Glass Materials (4)
Powder synthesis, powder compaction and densification via different processing routes. Phase equilibria and crystallography in ceramic materials. Sintering, liquid and vapor phase processing and single crystal growth. Control of the microstructural development and interfacial properties to optimize properties for structural, thermal, electrical, or magnetic use. Topics in processing and use of advanced ceramic materials. Glass formation and structure, phase separation, viscous flow and relaxation. *Prerequisite: consent of instructor.*

240A. Scanning Electron Microscopy and X-Ray Microanalysis (4)
Electron optics, electron-beam-specimen interactions. Image formation in the SEM. The role of specimen and detector in contrast formation. Imaging strategies. X-ray spectral measurements. Qualitative and quantitative X-ray microanalysis. Materials specimen preparation. *Prerequisite: consent of instructor. The laboratory section will teach the operation of the microscope to conduct material analysis via SEM.*

240B. Transmission Electron Microscopy (4)
Operation and calibration of the TEM, lens defects and resolution, formation of images and diffraction patterns, electron diffraction theory (kinematic dynamical), indexing diffraction patterns, diffraction contrast. Quantitative analysis of crystal defects, phase contrast, and specimen preparation. *Prerequisite: MS 240A or consent of instructor. The laboratory section will teach the operation of the microscope to conduct material analysis via TEM.*

240C. Analytical Electron Microscopy (4)
Concepts of AEM and AEM capabilities, alignment in the AEM. Imaging modes in the AEM (TEM and STEM). Quantitative X-ray microanalysis. Limits of microanalysis. Electron energy loss spectroscopy (EELS). Microdiffraction. Convergent beam electron diffraction (CBED), and high-resolution transmission electron microscopy (HRTEM). *Prerequisite: MS 240B or consent of instructor. The laboratory section will teach the operation of the microscope to conduct material analysis via AEM.*

242. X-Ray Diffraction Analysis of Materials (4)
This class will cover the physics of x-ray diffraction and its application to the analysis of crystal structure, grain size, grain orientation, surface roughness, epitaxy, film thickness, etc. Experimental techniques to be discussed and will include theta- 2 theta diffractometry, high resolution x-ray rocking curves, Laue patterns, pole figures, reflectivity, small engle scattering, laboratory experiments, and computer simulation. *Prerequisite: consent of instructor.*

243. Modern Materials Analysis (4)
Analysis of the near surface of materials via ion, electron, and x-ray spectroscopes. Topics to be covered include particle solid interactions. Rutherford Backscattering, secondary ion mass spectroscopy, electron energy loss spectroscopy, particle induced x-ray emission, Auger electron spectroscopy, extended x-ray absorption fine structure and channeling. *Prerequisite: consent of instructor.*

250. Display Technologies (4)
This class will introduce various types of information displays such as CRTs, plasma panels, field emission devices, and liquid crystals. The fundamentals of luminescence in solids will be covered. The performance parameters which need to be evaluated for display performance will be described. *Prerequisite: B.S. in a science or engineering field.*

290. Topics in Materials Science (4)
A course to be given at the discretion of the faculty on topics of current interest in materials science.

295. Research Conference (2)
Group discussion of research activities and progress of group members. *Prerequisite: consent of instructor.*

296. Independent Study (4)
Prerequisite: consent of instructor.

299. Graduate Research (1-12)
(S/U grades only.)

Subject to the approval of a faculty adviser, students may also choose from the following courses offered by departments participating in the Materials Science and Engineering Program (see the relevant pages of this catalog for descriptions):

Mechanical and Aerospace Engineering (MAE)

MAE 229A. Mechanical Properties (4)

MAE 229B. Advanced Mechanical Behavior (4)

MAE 231A. Foundations of Solid Mechanics (4)

MAE 231B. Elasticity (4)

MAE 232A-B-C. Finite Element Methods in Solid Mechanics (4-4-4)

MAE 233A. Fracture Mechanics (4)

MAE 233B. Micromechanics (4)

MAE 233C. Advanced Mechanics of Composite Materials (4)

MAE 238. Stress Waves in Solids (4)

MAE 251. Thermodynamics (4)

MAE 256. Rheology of Fluids (4)

MAE 257A. Polymer Processing (4)

Chemistry

Chem 240. Electrochemistry (4)

Electrical and Computer Engineering (ECE)

ECE 230A. Solid State Electronics (4)

ECE 230B. Solid State Electronics (4)

ECE 230C. Solid State Electronics (4)

ECE 231. Thin Film Phenomena (4)

ECE 233. Structure of Solids (4)

ECE 234B. Advanced Study of Defect in Solids (4)

ECE 237. Modern Materials Analysis (4)

ECE 239. Nanometer-Scale Probes and Devices (4)

ECE 246A. Physics/Magnetic Recording Materials (4)

Physics

Phys. 133/219. Condensed Matter/Materials Science Laboratory (2)

Phys. 152B/232. Electronic Materials (4)

Phys. 211A. Solid State Physics (5)

Phys. 211B. Solid State Physics (4)

Structural Engineering (SE)

SE. 254. Anelasticity (4)