Materials Science and Engineering Program

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Materials science and engineering is concerned with the structure, properties, and applications of materials. The university-wide Materials Science and Engineering Program (MSE) at UC San Diego aims to provide fundamental knowledge for understanding of materials with the objective of predicting, modifying, and tailoring the properties of materials to yield enhanced material performance.

The foundations of materials science are the basic sciences of physics, chemistry, mathematics, and engineering principles. The interdisciplinary nature of the program at UCSD is ideally suited to address this requirement. The graduate students in the Materials Science and Engineering Program benefit from the unique and broad combination of faculty members and research facilities existing at UCSD, in the Departments of Mechanical and Aerospace Engineering, Electrical and Computer Engineering, NanoEngineering, Physics, Chemistry and Biochemistry, Bioengineering, Structural Engineering, Scripps Institution of Oceanography, as well as the School of Medicine and the Division of Biological Sciences. Students pursuing their M.S. or Ph.D. degree in the MSE Program can have any faculty member from these participating departments and schools in UCSD as their thesis advisor or co-advisor, based on matching of the interests and/or financial support arrangements.

Of particular emphasis within the program are: a study of microstructure-property relationships; design of electronic, superconducting, magnetic, and nano materials for electronic and high-tech device and energy applications; optical and chemical materials for telecom and display applications; biomaterials and medical device materials for biotech applications; experimental investigation and theoretical modeling of the mechanical behavior of materials; and advanced composite materials for civil structures.

THE GRADUATE PROGRAM

The Materials Science and Engineering Program at UC San Diego is interdisciplinary, with participation of faculty members from several departments. Faculty from the following departments participate in the Materials Science and Engineering Program: Mechanical and Aerospace Engineering, Physics, Scripps Institution of Oceanography, Structural Engineering, Electrical and Computer Engineering, NanoEngineering, Chemistry and Biochemistry, Bioengineering, the Division of Biological Sciences, the School of Medicine, and the School of Pharmacy. The director of the program, in consultation with the executive committee, carries out the governance 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 pursuing the M.S. and Ph.D. in materials science and engineering at UCSD would normally include a degree in materials sciences, or in engineering or physical sciences, such as physics, chemistry, biology, geology, and related disciplines. Students are expected to have an adequate mathematics, physics, chemistry, and related basic sciences background, as well as acceptable GPA and GRE scores.

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 four Mandatory Core Courses and at least two of the six Elective Core Courses:
   Mandatory Core Courses
   MS 201A-B-C, MS 227
   Elective Core Courses (required to select at least two to fulfill requirements)
   MS 205A, MS 251A–B, MS 252, MS 253, PHYS 152A (Physics 211A can replace 152A with advisor's permission.) See "Courses" for description.
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 MS degree may be selected from an approved list of graduate courses with the consent of a faculty advisor.
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 advisor, 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 advisor.
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

For course descriptions not found in the UC San Diego General Catalog, 2010–11, please contact the department for more information.

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. (Cross-listed with MAE 271C.)

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.

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. (Cross-listed with MAE 229.)

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) (Cross-listed with MAE 273A.)

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. (Cross-listed with ECE 246A.)

227. Structure and Analysis 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.

236. Advanced Ceramic (4)
Topics include phase equilibria and crystallography, defects and thermodynamics (Kröger-Vink Notation), glass science, electrical and ionic transport behavior, Brouwer diagrams, powder synthesis and compaction, sintering theory and gain growth, mechanical, optical, magnetic, electrical properties, fuel cells. **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.

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. (Cross-listed with ECE 237.)

251A. Electronic and Photonic Properties of Materials (4)
The electronic and optical properties of metals, semiconductors, and insulators. The concept of the band structure. Electronic and lattice conductivity. Type I and Type II superconductivity. Optical engineering using photonic band gap crystals in one-, two-, and three-dimensions. Current research frontiers. **Prerequisites:** consent of the instructor. (Cross-listed with MAE 265A.)

251B. Magnetic Materials: Principles and Applications (4)
The basis of magnetism: classical and quantum mechanical points of view. Different kinds of magnetic materials. Magnetic phenomena including anisotropy, magnetostriction, domains, and magnetization dynamics. Current frontiers of nano-magnetics research including thin films and particles. Optical, data storage, and biomedical engineering applications of soft and hard magnetic materials. **Prerequisites:** consent of instructor. (Cross-listed with MAE 265B.)

252. Biomaterials (4)
This class will cover biomaterials and biomimetic materials. Metal, ceramic, and polymer biomaterials will be discussed. Emphasis will be on the structure-property relationships, biocompatibility/degradation issues and tissue/material interactions. Synthesis and mechanical testing of biomimetic

materials will also be discussed. **Prerequisite:** consent of instructor. (Cross-listed with MAE 266.)

253. Nanomaterials and Properties (4)
This course discusses synthesis techniques, processing, microstructural control, and unique physical properties of materials in nano-dimensions. Topics include nanowires, quantum dots, thin films, electrical transport, electron emission properties, optical behavior, mechanical behavior, and technical applications of nanomaterials. **Prerequisite:** consent of instructor. (Cross-listed with MAE 267.)

254. Frontier Micro-Electro-Mechanical Systems (MEMS)Materials and Devices (4)
Fabrication of Micro-Electro Mechanical Systems (MEMS) by bulk and surface micromachining of single crystal, polycrystal, and amorphous silicon and other materials. Performance issues including electrostatic, magnetic, piezoelectric actuations, residual stresses, deformation. Novel device applications, future trends in smart materials and nano-electro-mechanical (NEMS)systems. **Prerequisite:** consent of instructor. (Cross-listed with MAE 268.)

255. Presentations, Inventions, and Patents (4)
This course covers methodology and skills for oral and written presentations. Topics include preparation of presentation materials, presentation exercise, publication manuscripts, research work proposals, understanding and securing of inventions and intellectual properties, patent applications and licensing. **Prerequisite:** consent of instructor. (Cross-listed with MAE 269.)

256. Energy Materials and Applications (4)
This class will cover the fundamentals/engineering aspects of various energy materials based on metallic, ceramic, semiconductor; and chemical structures and their applications related to solar cells, fuel cells, batteries, fusion energy, and hydrogen storage will be discussed. (Cross-listed with MAE 278.) **Prerequisite:** consent of instructor/department stamp.

257. Polymer Science and Engineering (4)
Quantitative basic understanding of different branches of polymer science varying from polymer chemistry, characterization, thermodynamics, rheological properties, smart materials, self-assembly in biopolymers (natural)and synthetic polymers, and applications of polymers ranging from medicine to structure. (Cross-listed with BENG 242.) **Prerequisites:** graduate standing in bioengineering (BE 75)or materials science (MS 76)or consent of instructor.

258. Medical Device Materials (4)
In this interdisciplinary course, the nature, properties, and applications of various medical device materials will be discussed. The devices include coronary stents, catheters, drug delivery vehicles, and other implant, surgery, or therapeutics related devices. (Cross-listed with MAE 250.)

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 advisor, 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 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 238. Stress Waves in Solids (4)

MAE 251. Structure and Analysis of Solids (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 237. Modern Materials Analysis (4)

ECE 246A. Materials for Magnetic Recording (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)