Micro-Electro-Mechanical Systems (MEMS) and Nanotechnology

The field of Microelectromechanical Systems/Nanotechnology (MEMS/Nano) studies the integration of science, engineering, and technology in the length scale of micrometers and nanometers. As partial preparation for the degrees of Ph.D. and M.S. in the Mechanical and Aerospace Engineering Department, with a major field in MEMS and Nanotechnology, students should be able to demonstrate mastery of the subject matter described below.

Summary of Major Field Body of Knowledge:

Students should master the major field body of knowledge covered in the following courses:

MAE 280B (equiv. to EE M250B and BME M250B)
MAE 287

and a selection of 2 courses from the following (or other courses if supported by the research advisor and approved by the field chair in advance):

MAE 183B, 281, M282, C287L, 284, 231G, 283, 285, 250M

The written qualifying (preliminary) examination covers the entire major field body of knowledge.

More details concerning the major field body of knowledge can be found in the **Syllabus for the Major Field**, on the next page.

Minimum Requirements for Ph.D. Major Field Students:

The student must pass a written examination in the major field and satisfy other program requirements for the Ph.D. in the MAE Department besides completing all other formal University requirements.

Format of Written Qualifying Examination:

The Ph.D. preliminary exam in the MEMS/Nano Major Field is in both written and oral forms.

Timing of Written Qualifying Examination:

The exam is typically arranged near the end of each academic year. Students are strongly encouraged to take the exam in the first academic year. If failed, they can take it again in the second academic year from the time of admission to the Ph.D. program, and may not take the exam more than twice. The details of the exam will be announced each year, and students need to register for the exam in the department student affairs office before the announced deadline.

Link to old exams:

http://stdntsvcs.mae.ucla.edu/exam/index.htm

Ph.D. Minor Field Requirements:

Students who select MEMS/Nano as a minor field must pass three courses among the MEMS/Nano courses listed on the following page with a minimum GPA of 3.33. At least two must be at the graduate level, and at least one of the two must be from the MEMS/Nano core courses.

Syllabus for the Major Field in MEMS/Nanotechnology

The written qualifying (preliminary) exam tests the mastery of core materials in the MEMS/Nano field as well as the fundamentals of science and engineering. The specific body of knowledge tested includes materials from all of the MEMS/Nano core courses, as well as two of the MEMS/Nano specialty courses listed below.

MEMS/Nano Core Courses:

1. MEMS Fabrication — MAE M280B (equiv. to EE M250B and BME M250B)
   Course content:
   - Introduction to MEMS fabrication for advanced R&D of MEMS
   - Surface micromachining and bulk micromachining
   - Advance photolithography technologies
   - Thin film deposition
   - DRIE
   - Electroplating
   - Packaging
   - Bonding
   - Mechanical properties of thin film and residual stress,
   - Thermal processes, thermal diffusion, thermal budget and oxidation processes.
   - Ion implantation

2. Nanoscience and Biotechnology—MAE M287
   - Basic physical, chemical, and biological principles in nano sciences
   - Nanoscale materials prepared by various methods
   - Top-down and bottom-up nano fabrication techniques
   - Nano characterization
   - Applications of nano technology on electronics, biology, medicine, energy, environment, etc.

MEMS/Nano Specialty Courses:

3. Introduction to microscale and nanoscale manufacturing - MAE M183B (equivalent to EE M153, BE M153, ChE M153)
   - Introduction of micro- and nanofabrication
   - Photolithography
   - Electron beam lithography
   - Nanoimprint lithography and soft lithography
   - Self-assembly and chemical synthesis
   - SEM and AFM for nanostructure inspection
   - Physical and chemical etching processes
   - Physical and chemical deposition processes
   - Cleanroom experience: this class will also provide a hands-on experience for fabricating micro and nanostructures in a cleanroom environment in UCLA Microlab.

4. Microsciences—MAE 281
   - Issues of being in micrometers and nanometers in science and engineering
   - Important physical and chemical principles important in MEMS and Nanotechnology
   - Mechanical properties of materials in microscale
   - Surface tension and its relevance in MEMS
   - Single molecule mechanics

- Molecular motors

5. Microscopic Energy Transport—MAE 231G
    - Basics of statistical thermodynamics/quantum mechanics
    - Microscopic transport theory
    - Applications to semiconductor electronic/optoelectronic devices
    - Applications to MEMS/NEMS devices
    - Applications to nanostructures
    - Applications to biological systems

6. MEMS Device Physics and Design—EE250B/MAE M282
   Prerequisite: EE M250A/MAE M280 or equivalent, to be approved by the instructor
    - Critical understanding of various transduction principles
    - Design, production, and characterization of MEMS devices
    - Sensing (piezoelectric, capacitive, magnetic, etc.)
    - Actuation (electrostatic, electromagnetic, thermal, piezoelectric, SMA, etc.)
    - Layout and design rules, Foundry services (MUMPs, MOSIS, SUMMiT, etc.)

7. Experimental Mechanics for Microelectromechanical Systems (MEMS)—MAE M283
    - Methods, techniques, and philosophies to characterize micro/nano electro-magneto-mechanical systems
    - Material and mechanical property characterization
    - Crystallographic and anisotropic properties
    - Emerging approaches for micro/nano scale characterization
    - Biomechanical testing techniques

8. Sensors, Actuators, and Signal Processing—MAE284
    - Principles and performance of micro transducers
    - Design of experiments
    - Sensor and actuator spatial/temporal resolution, error analysis, uncertainty propagation, and data acquisition
    - Applications of micro transducers for distributed real-time control of systems

9. Interfacial Phenomena—MAE 285
    - Surface tension, surfactants, and interfacial forces
    - Interfacial thermodynamics
    - Interfacial hydrodynamics
    - Dynamics of the triple line
    - Applications to wetting, change of phase, foams and emulsions, MEMS, and biological systems

10. Nanoscale Fabrication, Characterization, and Biodetection Lab—MAE C287L
    Prerequisite: MAE M180 and MAE M180L or equivalent, to be approved by the instructor
    - Basic physical, chemical, and biological principles in nano-areas
    - Top-down and bottom-up nanofabrication techniques
    - Nano characterization techniques
    - Biosensing technology

11. Introduction to Micro/Nano Fluids—MAE 250M
    - Fluid mechanics in macro and micro systems
    - Sedimentation
    - Diffusion
    - Osmotic pressure and equilibrium
    - Surface phenomena
    - Attractive van Waals interactions
    - The electrical double-layer and repulsive double-layer interactions

- Electrophoresis and Zeta potential
- Non-Newtonian fluid mechanics

Requirements for Ph.D. Major Field Students:

The basic program of study for the Ph.D. degree is built around the MEMS/Nano major field, one minor field, and three additional courses. There is no formal major field course requirement for the Ph.D. degree, but students must pass preliminary examination in MEMS/Nano field, which requires for the mastery of knowledge equivalent to the core courses for the field and specialty courses for the individual (see below). They should also satisfy the requirement for one minor field and successfully finish the three additional courses, of which at least two on the graduate level, approved by their faculty advisors**.**

Qualifying Examination:

After passing the preliminary exam and performing preliminary research on the dissertation topic, the student is ready to take the qualifying exam. The qualifying exam is in the form of oral presentation, but each student should prepare a prospectus that introduces the topic and outlines the research plan.

A qualifying exam committee needs to be formed with a composition that conforms to the following rules:

- must consist of at least four ladder faculty members (i.e., assistant, associate, or full professors)
- three faculty members must be within the department (your advisor is chair of this committee)
- one faculty member must be from outside of the department
- adjunct faculty members, industrial collaborators, and other non-academic advisors can serve on the committee as additional non-voting members

Ph.D. Dissertation:

A thesis must be completed under the direction of a faculty advisor. It must be signed by four faculty members, whose composition follows the following rules:

- must consist of at least four ladder faculty members (i.e., assistant, associate, or full professors)
- three faculty members must be within the department
- one faculty member must be from outside of the department

M.S. Comprehensive Examination:

MAE students in the M.S. comprehensive examination plan can also take the preliminary exam to satisfy the requirement for a comprehensive exam for an M.S. degree.