Department of Materials Science and Engineering

http://www.mse.utdallas.edu/index.html

Faculty

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Associate Professors: Amy Walker, Jiyoung Kim
Assistant Professors: Christopher Hinkle
Affiliated Faculty: Kenneth J. Balkus (Chemistry), Ray H. Baughman (Chemistry), Cyrus D. Cantrell (Electrical Engineering), Kyeongjae Cho (Physics), Santosh R. D'Mello (Biology), Rockford K. Draper (Biology), John P. Ferraris (Chemistry), Yuri Gartstein (Physics), Robert Glosser (Physics), Juan E. González (Biology), Steven R. Goodman (Biology), Wenchuang Hu (Electrical Engineering), Gil S. Lee (Electrical Engineering), Jeong-Bong Lee (Electrical Engineering), Sanjeev K. Manohar (Chemistry), Inga Holl Musselman (Chemistry), Lawrence J. Overzet (Electrical Engineering), Eric Vogel (Electrical Engineering), Anvar A. Zakhidov (Physics)
Adjunct Faculty: H. Edwards (Texas Instruments), E. Forsythe (Army Research Laboratory), R. Irwin (Texas Instruments), M. Quevedo-Lopez

Objectives

The program leading to the M.S. degree in materials science and engineering provides intensive preparation for professional practice in modern materials science by those engineers who wish to continue their education. Courses are offered at a time and location convenient for the student who is employed on a full-time basis.

The objective of the doctoral program in materials science and engineering is to prepare individuals to perform original, cutting edge research in the broad areas of materials science, including areas such as nano-structured materials, electronic, optical and magnetic materials, bio-mimetic materials, polymeric materials, MEMS materials and systems, organic electronics, and advanced processing of modern materials.

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Advanced Electron Microscopy Laboratory

Focused Ion Beam /Scanning Electron Microscopy

The focused ion beam system is a FEI Nova 200 NanoLab which is a dual column SEM/FIB. It combines ultra-high resolution field emission scanning electron microscopy (SEM) and focused ion beam (FIB) etch and deposition for nanoscale prototyping, machining, 2-D and 3-D characterization, and analysis. Five gas injection systems are available for deposition (e.g. Pt, C, SiO_2) and etching (e.g. Iodine for metals, and a dielectric etch). Nanoscale chemical analysis is done with energy dispersive X-ray spectroscopy (EDS). A high resolution digital patterning system controlled from the User Interface is also available. Predefined device structures in Bitmap format can be directly imported to the patterning system for nanoscale fabrication. The FEI Nova 200 is also equipped with a Zyvex F100 nano-manipulation stage, which includes four manipulators with 10 nm positioning resolution. The four manipulators can be fitted with either sharp whisker probes for electrically probing samples or microgrippers for manipulating nanostructures as small as 10 nanometers. This is the first instrument of its kind in the world that combines a dual beam FIB with the F100 nanomanipulator, providing unparalleled nanofabrication and nanomanipulation.

High-Resolution Transmission Electron Microcopy

The facility operates and maintains two state-of-the-art transmission electron microscopes (TEM), and a host of sample preparation equipments. It also provides microscopy computing and visualization capabilities. Techniques and equipment available includes the following: (i) *High Resolution Structural Analysis* - The high-resolution imaging TEM is a JEOL 2100 F which is a 200kV field emission TEM. Its capability includes atomic scale structural imaging with a resolution of better than 0.19 nm, and in-situ STM/TEM. (ii) *High Resolution Chemical and Electronic Structure Analysis* **-** High resolution analytical TEM is a second JEOL 2100F field emission TEM/STEM equipped with an energy dispersive x-ray spectrometer (EDS), an electron energy loss spectrometer (EELS), and a high angle Z-contrast imaging detector. This instrument performs chemical and electronic structure analysis with a spatial resolution of better than 0.5 nm in EELS mode and is also capable of spectrum imaging and mapping. The image resolution in the chemically sensitive Z-contrast scanning TEM (STEM) mode will be about 0.14 nm. Its capability also includes in-situ cryogenic cooling and heating, and a computer control system for remote microscopy operation.

X-ray Diffraction Suite

A Rigaku Ultima III X-ray Diffractometer system is available for thin film diffraction characterization. The system is equipped with a cross beam optics system to permit either High-resolution parallel beam with a motor controlled multilayer mirror, or a Bragg-Brentano Para-Focusing beam (without the multilayer mirror) which are permanently mounted, pre-aligned and user selectable with no need for any interchange between components. Curved graphite crystal or Ge monochrometers are also available. An integrated annealing attachment permits the *in-situ* examination of film structure up to 1500°C. The instrument enables a variety of applications including in-plane and normal geometry phase identification, quantitative analysis, lattice parameter refinement, crystallite size, structure refinement, residual stress, density, roughness (from reflectivity geometries), and depth-controlled phase identification. Detection consists of a computer controlled scintillation counter. Sample sizes up to 100 mm in diameter can be accommodated on this system. A new Rigaku Rapid Image Plate Diffractometer system is also available for small spot (30mm - 300mm) XRD work. The digital image plate system enables the acquisition of diffraction data over a 204° angle with a rapid laser scanning readout system.An integrated annealing attachment permits the *in-situ* examination of film structure up to 900C on this system. A complete set of new control, database and analysis workstations and software is associated with these new systems.

Wafer Bonding Laboratory

An UHV wafer bonding unit, especially designed to use surface characterization and thin-film deposition techniques to measure and control substrate and interface chemistry within limits necessary to make heterojunction devices, is available to produce integrated heterostructures with well controlled chemistry that are tractable for quantitative nanostructural and properties measurements. This unit is capable of synthesizing interfaces by direct wafer bonding and/or in-situ thin film deposition method, and offers greater flexibility for producing advanced integrated artificial structures. It consists of five interconnected ultra high vacuum (UHV) chambers for in-situ surface preparation and analysis, addition of interface interlayers by e-beam or UHV sputter deposition, a bonding chamber, and a sample entry and preparation chamber. The base pressure is 2×10^{-10} Torr. Orientation of the bonded pairs can be controlled to ~ 0.1 degree prior to bonding. Ex-situ surface preparations using etching and low energy reactive plasma cleaning is done in a cleanroom to protect substrates prior to insertion in the bonding instrument. An atomic force microscopy (AFM) is also available to provide direct measurements of these effects, to supplement the indirect information of RHEED.

Computational Materials Science Laboratory

Materials modeling software tools and hardware facilities are available for nanoscale materials research. Atomistic modeling software tools are used for structure and dynamic analysis of diverse material systems at nanoscales, and the examples include nanoelectronic materials and nanomaterials for renewable energy applications. For quantum mechanical analysis of materials, density functional theory (DFT) software tools (VASP, ABINIT, PWSCF, and SIESTA) are used on local parallel computing cluster. In-house quantum transport modeling software tool is used for I-V calculation of nanoelectronic devices using the non-equilibrium Green's function (NEGF) method. These software and hardware tools are also used for class projects of MSEN 5377.

Cleanroom Research Laboratory

The new cleanroom facility located in the Natural Science and Engineering Research Laboratory (http://www.utdallas.edu/eecs/cleanroom/) is utilized for materials and device research. The facility has 5,000 sq. ft. of class 10,000 space. This facility contains semiconductor processing equipment including optical and e-beam lithography, chemical processing hoods, evaporation and sputter deposition systems, as well as a wide variety of material and processing diagnostics.

In addition to the facilities on campus, cooperative arrangements have been established with many local industries to make their facilities available to U.T. Dallas graduate engineering students.

Master of Science in Materials Science and Engineering

Admission Requirements

The University's general admission requirements are discussed here.

A student lacking undergraduate prerequisites for graduate courses in Materials Science and Engineering must complete these prerequisites or receive approval from the graduate adviser and the course instructor.

A diagnostic exam may be required. Specific admission requirements follow.

The student entering the MSEN program should meet the following guidelines:

- Student has met standards equivalent to those currently required for admission to the Ph.D. or Master's degree programs in Electrical Engineering, Chemistry, Physics, or Biology.
- a grade-point average in graduate-level course work of 3.5 or better on a 4-point scale
- GRE scores of 500, 700 and 4 for the verbal, quantitative and analytical writing components, respectively, are advisable based on our experience with student success in the program.

Students who fulfill some of the above requirements, if admitted conditionally, will be required to take graduate level courses as needed to make up any deficiencies.

Degree Requirements

The University's general degree requirements are discussed here.

The MSEN M.S. degree requires a minimum of 33 semester hours.

All students must have an academic advisor and an approved degree plan. These are based upon the student's choice of concentration. Courses taken without advisor approval will not count toward the 33 semester-hour requirement. Successful completion of the approved course of studies leads to the M.S. degree.

M. S. students undertaking the thesis option must carry out a research project under the direction of a member of the Materials Science and Engineering Affiliated Faculty and complete and defend a thesis on the research project. A Supervisory Committee will be appointed once the faculty member accepts the student for a research project. The rules for the thesis defense are specified by the Office of the Dean of Graduate Studies.

For each of the proposed degree programs, students must pass the following core courses with a grade of B or better:

Note: the presence of a course number in parentheses indicates that this course will be cross-listed with an existing course.

- MSEN 5310 Thermodynamics of Materials
- MSEN 5360 Materials Characterization
- MSEN 6324 (EE 6324) Electronic, Optical and Magnetic Materials
- MSEN 6319 Quantum Mechanics for Materials Scientists

A student may petition for waiver of core courses, and if the Materials Science and Engineering Affiliated Faculty, or a designated committee, finds that the student has mastered the course material, the student may replace that core course with an elective course for a total of twelve semester credit hours.

A minimum of 9 semester credit hours will be required from the Advanced Course List

- MSEN 5340 Advanced Polymer Science and Engineering
- MSEN 5370 Ceramics and Metals
- MSEN (5377) (PHYS 5377) Computational Physics of Nanomaterials
- MSEN 6310 Mechanical Properties of Materials
- MSEN 6330 Phase Transformations
- MSEN 6350 Imperfections in Solids
- MSEN 6377 (PHYS 6377) Physics of Nanostructures: Carbon Nanotubes, Fullerenes, Quantum Wells, Dots and Wires

The remaining credit hours are to be taken from the following list of Specialized Courses (or approved electives from Physics, Chemistry, or Biology):

- MSEN 5300 Introduction to Materials Science
- MSEN 5331 (CHEM 5331) Advanced Organic Chemistry I
- MSEN 5333 (CHEM 5333) Advanced Organic Chemistry II
- MSEN 5341 (CHEM 5341) Advanced Inorganic Chemistry
- MSEN 5344 Thermal Analysis
- MSEN 5353 Integrated Circuit Packaging

- MSEN 5355 (CHEM 5355) Analytical Techniques I
- MSEN 5356 (CHEM 5356) Analytical Techniques II
- MSEN 5361 Fundamentals of Surface and Thin Film Analysis
- MSEN 5371 (PHYS 5371) Solid State Physics
- MSEN 5375 (PHYS 5375) Electronic Devices Based On Organic Solids
- MSEN 5383 (PHYS 5383 and EE 5383) Plasma Technology
- MSEN 5410 (BIOL 5410) Biochemistry of Proteins and Nucleic Acids
- MSEN 5440 (BIOL 5440) Cell Biology
- MSEN 6313 (EE 6313) Semiconductor Opto-Electronic Devices
- MSEN 6320 (EE6320) Fundamentals of Semiconductor Devices
- MSEN 6321 (EE6321) Active Semiconductor Devices
- MSEN 6322 (EE6322) Semiconductor Processing Technology
- MSEN 6340 Advanced Electron Microscopy
- MSEN 6341 Advanced Electron Microscopy Laboratory
- MSEN 6358 (BIOL 6358) Bionanotechnology
- MSEN 6361 Deformation Mechanisms in Solid Materials
- MSEN 6362 Diffraction Science
- MSEN 6371 (PHYS6371) Advanced Solid State Physics
- MSEN 6374 (PHYS6374) Optical Properties Of Solids
- MSEN 7320 (EE7320) Advanced Semiconductor Device Theory
- MSEN 7382 (EE7382) Introduction to MEMS
- MSEN 7V80 Special Topics in Materials Science and Engineering
- MSEN 8V40 Individual Instruction in Materials Science and Engineering
- MSEN 8V70 Research In Materials Science and Engineering
- MSEN 8V98 Thesis

Doctor of Philosophy in Materials Science and Engineering

Admission Requirements

The University's general admission requirements are discussed here.

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A student lacking undergraduate prerequisites for graduate courses in Materials Science and Engineering must complete these prerequisites or receive approval from the graduate adviser and the course instructor.

A diagnostic exam may be required. Specific admission requirements follow.

The student entering the MSEN program should meet the following guidelines:

- Student has met standards equivalent to those currently required for admission to the Ph.D. or Master's degree programs in Electrical Engineering, Chemistry, Physics, or Biology.
- a grade-point average in graduate-level course work of 3.5 or better on a 4-point scale
- GRE scores of 500, 700 and 4 for the verbal, quantitative and analytical writing components, respectively, are advisable based on our experience with student success in the program.

Students who fulfill some of the above requirements, if admitted conditionally, will be required to take graduate level courses as needed to make up any deficiencies.

Degree Requirements

The University's general degree requirements are discussed here.

The MSEN Ph.D. requires a minimum of 60 semester hours beyond the Master's degree.

All students must have an academic advisor and an approved degree plan. Courses taken without advisor approval will not count toward the 60 semester-hour requirement. Successful completion of the approved course of studies leads to the MSE.

Each doctoral student must carry out original research in the area of Materials Science and Engineering, under the direction of a member of the Materials Science and Engineering Affiliated Faculty, and complete and defend a dissertation on the research project. A Supervisory Committee will be appointed once the faculty member accepts the student for a research project. Students must be admitted to doctoral candidacy by passing a Qualifying Exam, which will be administered at approximately the time that the students have completed their course work. The rules for the dissertation research and defense are specified by the Office of the Dean of Graduate Studies.

For each of the proposed degree programs, students must pass the following core courses with a grade of B or better:

Note: the presence of a course number in parentheses indicates that this course will be cross-listed with an existing course.

- MSEN 5310 Thermodynamics of Materials
- MSEN 5360 Materials Characterization
- MSEN 6319 Quantum Mechanics for Materials Scientists
- MSEN 6324 (EE 6324) Electronic, Optical and Magnetic Materials

A student may petition for waiver of core courses, and if the Materials Science and Engineering Affiliated Faculty, or a designated committee, finds that the student has mastered the course material, the student may replace that core course with an elective course for a total of twelve semester credit hours.

A minimum of 9 semester credit hours will be required from the Advanced Course List

- MSEN 5340 Advanced Polymer Science and Engineering
- MSEN 5370 Ceramics and Metals
- MSEN (5377) (PHYS 5377) Computational Physics of Nanomaterials
- MSEN 6310 Mechanical Properties of Materials
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The remaining credit hours are to be taken from the following list of Specialized Courses (or approved electives from Physics, Chemistry, or Biology):

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- MSEN 8V98 Thesis
- MSEN 8V99 Dissertation