**Department of Materials Science and Engineering**

[http://www.mse.utdallas.edu/](http://www.mse.utdallas.edu/index.html)

**Faculty**

**Professors:** Yves J. Chabal (Head), Massimo V. Fischetti, Bruce E. Gnade, Julia W. Hsu, Moon J. Kim, Robert M. Wallace
**Associate Professors:** Kyeongjae (KJ) Cho, Lev D. Gelb, Jiyoung Kim, Manuel Quevedo, Eric M. Vogel, Amy V. Walker

**Assistant Professors:** Christopher L. Hinkle, Walter E. Voit

**Research Professors**: Wiley P. Kirk (Associate Head), Padmakumar Nair

**Professor Emeritus**: Don W. Shaw

**UTD Affiliated Faculty:** Mark Lee (Physics), Anvar Zakhidov (Physics), Anton Malko (Physics), Ray H. Baughman (Chemistry), Mihaela Stefan (Iovu) (Chemistry), Walter Hu (Electrical Engineering), Gil S. Lee (Electrical Engineering), Matthew J. Goeckner (Electrical Engineering), Larry J. Overzet (Electrical Engineering), JB Lee (Electrical Engineering), Hongbing Lu (Mechanical Engineering), Fatemeh Hassinopour (Mechanical Engineering)

**Adjunct Faculty:** Luigi Colombo (Texas Instruments), Husam Alshareef (KAUST, Saudia Arabia), Richard Irwin (Texas Instruments), Prashant Majhi (SEMATECH, Austin, Texas), Bin Shan (Huazhong University of Science and Technology), Glen Birdwell (Army Research Laboratories), Mathew David Halls (Materials Design), Oleg Lourie (Nanofactory Instruments Inc.)

**Objectives**

The objective of the Master of Science (M.S.) degree in materials science and engineering is to provide intensive preparation for the professional practice in modern materials science by those engineers and scientists who wish to continue their education. Courses are offered at times and locations convenient for the student who is employed on a full-time basis.

The objective of the Doctor of Philosophy (Ph.D.) program in materials science and engineering is to prepare individuals to perform original, cutting-edge research in materials science, particularly in the areas of nano-structured materials, electronics, optical and magnetic materials, bio-mimetic materials, polymeric materials, MEMS materials and systems, organic electronics, and advanced processing of modern materials.

**Scholarship Opportunities**

The Erik Jonsson School of Engineering and Computer Science offers competitive scholarship awards for very well qualified students. Interested students should request application materials by contacting the Department of Materials Science and Engineering.

The University’s general admission requirements are discussed [here](http://www.utdallas.edu/dept/graddean/).

 Specific admission requirements are as follows:

* Student has met standards equivalent to those currently required for admission to the Ph.D. or Master’s degree programs in Materials Science, Electrical Engineering, Chemistry, Physics, or Biology.
* A grade-point average in undergraduate-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 only some of the above requirements, if admitted conditionally, will be required to take graduate level courses as needed to make up any deficiencies.

The University’s general degree requirements are discussed [here](http://www.utdallas.edu/dept/graddean/).

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

M.S. students undertaking the non-thesis option must complete at least 33 semester credit hours of coursework with a grade of B or better.

M.S. students undertaking the thesis option must carry out a research project under the direction of a faculty or affiliated faculty in Materials Science and Engineering, and complete and defend a thesis on the research project, but they need only complete the four core courses and 9 semester credit hours of advanced course work.

students must obtain a grade of B¯ or better in each class and maintain an average core class GPA of at least 3.0 to remain in good standing and satisfy their degree requirements

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

Note: the presence of a course number in parentheses indicates that this course is cross-listed in another department.

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

A minimum of 9 semester credit hours of advanced coursework is required, from the following list:

* MSEN 5340 (CHEM 5340) Advanced Polymer Science and Engineering
* MSEN 5361 Fundamentals of Surface and Thin Film Analysis
* MSEN 5370 Ceramics and Metals
* MSEN 5377 (PHYS 5377) Computational Physics of Nanomaterials
* MSEN 6310 (MECH 6301) Mechanical Properties of Materials
* MSEN 6320 (EEMF 6320) Fundamentals of Semiconductor Devices
* MSEN 6330 Phase Transformations
* MSEN 6340 Advanced Electron Microscopy
* MSEN 6341 Advanced Electron Microscopy Laboratory
* 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, Biology, or Electrical and Mechanical Engineering):

* MSEN 5300 (PHYS 5376) Introduction to Materials Science
* MSEN 5320 Materials Science for Sustainable Energy
* 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 5371 (PHYS 5371) Solid State Physics
* MSEN 5375 (PHYS 5375) Electronic Devices Based On Organic Solids
* MSEN 5383 (PHYS 5383 and EEMF 5383) Plasma Technology
* MSEN 5410 (BIOL 5410) Biochemistry of Proteins and Nucleic Acids
* MSEN 5440 (BIOL 5440) Cell Biology
* MSEN 6313 (EEOP 6313) Semiconductor Opto-Electronic Devices
* MSEN 6321 (EEMF 6321) Active Semiconductor Devices
* MSEN 6322 (EEMF 6322, MECH 6322) Semiconductor Processing Technology
* MSEN 6348 (EEMF 6348) Lithography and Nanofabrication
* MSEN 6358 (BIOL 6358) Bionanotechnology
* MSEN 6361 (MECH 6361) Deformation Mechanisms in Solid Materials
* MSEN 6362 Diffraction Science
* MSEN 6371 (PHYS 6371) Advanced Solid State Physics
* MSEN 6374 (PHYS 6374) Optical Properties Of Solids
* MSEN 6382 (EEMF 6382) Introduction to MEMS
* MSEN 7320 (EEMF 7320) Advanced Semiconductor Device Theory
* 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**

The University’s general admission requirements are discussed [here](http://www.utdallas.edu/dept/graddean/).

* Student has met standards equivalent to those currently required for admission to the Ph.D. or Master’s degree programs in Materials Science, Electrical Engineering, Chemistry, Physics, or Biology.
* a grade-point average in undergraduate-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.

The University’s general degree requirements are discussed [here](http://www.utdallas.edu/dept/graddean/).

The MSEN Ph.D. requires a minimum of 75 semester hours beyond the baccalaureate degree. These credits must include at least 30 semester hours of graduate-level courses in MSEN.

All students must have an academic advisor and an approved degree plan. Courses taken without advisor approval will not count toward the 75 semester-hour requirement.

Each doctoral student must carry out original research in the area of Materials Science and Engineering, under the direction of a faculty or affiliated faculty of Materials Science and Engineering, and complete and defend a dissertation on the research project. Students must be admitted to doctoral candidacy by passing a Qualifying Exam, which will be administered near the time that the students have completed their course work. Upon passing the Qualifying Exam, students must present and defend a Research Proposal with their Supervisory Committee within approximately nine months or sooner after passing the Qualifying Exam.

students must obtain a grade of B¯ or better in each class and maintain an average core class GPA of at least 3.0 to remain in good standing and satisfy their degree requirements

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* MSEN 5360 Materials Characterization
* MSEN 6319 Quantum Mechanics for Materials Scientists
* MSEN 6324 (EEMF 6324) Electronic, Optical and Magnetic Materials

Note: the presence of a course number in parentheses indicates that this course is cross-listed in another department.

A student may petition for waiver of core courses, and if the MSEN faculty, or a designated committee, finds that the student has mastered the course material, the student may replace that core course with elective courses for up to a total of twelve semester credit hours.

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* MSEN 6382 (EEMF 6382) Introduction to MEMS
* MSEN 7320 (EEMF 7320) Advanced Semiconductor Device Theory
* 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
* MSEN 8V99 Dissertation

**Description of Facilities Available for Conducting Research**

A limited list of the extensive array of the materials characterization, synthesis, and processing tools that exist in the Department for student use in research are described below.

**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, SiO2) 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 2x10-10 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.

**Molecular Beam Epitaxy**

The ability to grow materials an atomic layer at a time is provided by molecular beam epitaxy (MBE). In particular three MBE deposition systems are linked together with a UHV transfer module. The first system, V80S, is designed to grow undoped and doped group-IV compounds such as Si, Ge, and strained Si/Ge superlattices structures. Doping *n* and *p*-type is done with Sb and B respectively. The vertical growth chamber in this system incorporates two electron-beam evaporators for Si and Ge and two effusion cells for doping. In addition it has a preparation chamber with a high temperature heating stage. The second chamber, V80H, features a horizontal growth chamber, eight effusion cells, and a preparation chamber. It is designed to grow II-VI materials such as BeTe, BeSe, ZnSe, ZnS, BeTeSe, and CdSeTe, epilayers as well as quantum well and superlattice structures. It also has an atomic N plasma source for *p*-doping and ZnCl2 for *n*-doping. The third system is identical to the second one; however, this system is used to grow III-V materials such as GaAs, InGaAs, and AlGaAs and to dope with Be and Si. VG Instruments built all three systems. They are fully controlled by computers and equipped with high-capacity, vacuum-pumping units that operate at a base pressure in the low 10-10 mbar range without liquid nitrogen cooling. Each growth chamber is equipped with various types of analytical tools such as RHEED and QMS.

**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 in MSEN 5377.

**Cleanroom Research Laboratory**

The cleanroom facility located in the Natural Science and Engineering Research Laboratory 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. More details about this facility can be found at this [location](http://www.utdallas.edu/research/cleanroom/).

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.