DEPARTMENT OF APPLIED PHYSICAL SCIENCES (GRAD)

Contact Information
Department of Applied Physical Sciences
Visit Program Website (http://aps.unc.edu)
Richard Superfine, Chair
M. Gregory Forest, Vice Chair
Sean Washburn, Associate Chair for Graduate Studies

The Department of Applied Physical Sciences at the University of North Carolina at Chapel Hill is an interdisciplinary graduate program that brings together faculty members from chemistry, mathematics, physics and astronomy, and various departments across the University to engage in research and training in applications of the physical sciences. The primary areas of emphasis in the program are optical and electronic materials, nanomaterials, polymers, and biomaterials. Students pursuing M.S. and Ph.D. degrees in materials science begin their studies with a core curriculum covering the fundamentals of materials, including their structures, surfaces, fabrication, thermodynamics, and materials science laboratory techniques. They continue with elective courses offered by the curriculum or the other departments as appropriate to their area of research concentration. Graduate students engage in research under the supervision of one of the participating materials science faculty in the Department of Applied Physical Sciences.

Research Interests
The four areas of research emphasized in the program are electronic, nano, polymer, and biomaterials. These four areas are not discrete, however, as research projects in electronic polymers, nonlinear optics of polypeptides on surfaces, liquid crystals, and wear in polyethylene artificial joints demonstrate. Individual faculty members may have research interests in more than one of the primary areas, and may collaborate with others to address all four. For detailed information on the graduate program, please consult the Web site (g-admit-apsc@unc.edu) or call the graduate student coordinator at 919-962-4703.

Facilities and Equipment
Students and faculty members in the curriculum have access to the following central facilities located in various departments: NMR (2), computer modeling and computer graphics, confocal microscopy, electron microscopy (SEM, TEM, and STEM), FIB, glass shop, machine shop (2), laser lab, mechanical testing, mass spectroscopy, and X-ray diffraction. In addition, a variety of equipment is located in individual research laboratories. This includes equipment for thermal analysis; polymer synthesis; FTIR, UV-Vis, Raman, and photoluminescence spectroscopy; ellipsometry; CVD; MBE; thermal oxidation; AFM; electrical measurements; nonlinear optics; and low temperatures and high pressures. Facilities at North Carolina State University in Raleigh and MCNC in Research Triangle Park are also available.

Fellowships and Assistantships
Teaching assistantships are available to qualified graduate students. The duties of teaching assistants include teaching laboratory sections, assisting in the supervision of advanced laboratories, teaching recitation sections, and grading papers. Summer support is generally available. Research assistantships are also offered.

Degree Requirements
The Ph.D. degree requirements include completion of a suitable set of courses, cumulative written comprehensive exams, a preliminary doctoral oral exam, an original research project culminating in a dissertation, and a final oral exam. The M.S. degree requirements include completion of a suitable set of courses, cumulative written comprehensive exams, a research project, and a final oral exam. The general regulations of The Graduate School govern credit hour, residency, and examination requirements.

Courses
All graduate students must pass the following courses or appropriate ones approved by the curriculum, or must have passed their equivalents elsewhere:

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<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Hours</th>
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<tbody>
<tr>
<td>APPL 470</td>
<td>Fundamentals of Materials Science</td>
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<td>APPL 473</td>
<td>Chemistry and Physics of Surfaces</td>
<td>3</td>
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<td>MTSC 615</td>
<td>Structure of Solids</td>
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<td>Statistical Thermodynamics</td>
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<td>Techniques in Materials Science</td>
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Each student also takes additional courses offered by the curriculum or participating departments, as appropriate for his or her area of study.

Comprehensive Exam
M.S. students must pass three core exams and one specialty exam. Ph.D. students must pass four core exams and two specialty comprehensive exams. Topics for the specialty exams will be research areas represented in the materials science program at UNC-Chapel Hill; core exams cover the fundamental knowledge of materials science. All students are required to complete the comprehensive exam by the end of their second year.

Preliminary Doctoral Oral Exam
Students are required to select a research adviser during the first year in graduate school and a thesis committee before they take the preliminary doctoral exam. To pass the preliminary doctoral oral exam, students must present to the dissertation committee and successfully defend their Ph.D. research proposal by the end of the third year.

Professors
Joseph M. DeSimone (Chemistry), Polymeric Materials Synthesis
Theo J. Dingemans (APS), High-Performance Polymers
Jinsong Huang (APS), Materials for Solar Conversion
Thomas Meyer (Chemistry - APS), Inorganic Chemistry, Solar Energy Conversion and Artificial Photosynthesis
Peter Mucha (Mathematics), Complex Systems, Networks, Complex Fluids
J. Michael Ramsey (Chemistry), Analytical Chemistry, Microfabricated Chemical Instrumentation, Microfluidics, Nanofluidics
Edward T. Samulski (Chemistry - APS), Liquid Crystals and Liquid Crystal Polymers
Richard Superfine (Physics and Astronomy - APS), Interfacial Ordering of Molecules
Sean Washburn (Physics and Astronomy - APS), Quantum Transport, Mechanical and Electrical Response of Nanostructures.

Associate Professors
Rene Lopez (Physics and Astronomy - APS), Optical Materials, Photonic Structures, Photovoltaics
Wei You (Chemistry - APS), Organic and Polymer Synthesis, Organic Solar Cells, Molecular Electronics, Organic Spintronics

Assistant Professors
Scott Warren (Chemistry - APS), Supramolecular and Solid-State Chemistry for Materials Design
Daphne Klotsa (APS), Active Matter
Ehssan Nazockdast (APS), Modeling/Simulation of Biophysical Phenomena

Affiliated Faculty
Nancy L. Albritton (BME and Chemistry), Signaling in Single Cells, Microfabricated Systems for Cellular Analysis
James Cahoon (Chemistry), Nanoparticle Synthesis and Characterization
Jianping Lu (Physics and Astronomy), Theoretical Studies of Materials
Laurie E. McNeil (Physics and Astronomy), Structure-Property Relations, Optical Spectroscopy
Jerry Meyer (Chemistry), New Materials for Energy Conversion
Lu-Chang Qin (Physics and Astronomy), Synthesis and Structure of Nanomaterials
Michael Rubinstein (Chemistry), Molecular Models of Polymers
Sergei S. Sheiko (Chemistry), Dynamics of Single Molecule on a Surface
Frank Tsui (Physics and Astronomy), Synthesis of Artificially Structured Materials
Yue Wu (Physics and Astronomy), Quasicrystals, Nanocrystals, Nanotubes and Molecular Motion in Polymers
Otto Zhou (Physics and Astronomy), Synthesis, Properties and Applications of Nanomaterials

APPL
Advanced Undergraduate and Graduate-level Courses
APPL 411. Practical Electronics for Everyone. 1 Credit.
Design and fabrication for practical electronics circuits, including interfacing with sensors and actuators.
Grading status: Letter grade.
APPL 412. Turning Your Entrepreneurial Ideas Into Reality. 3 Credits.
Students will work in groups on a semester project to turn their entrepreneurial ideas into reality.
Grading status: Letter grade.
APPL 413. LabView for Data Acquisition. 1 Credit.
The basics of data acquisition and hardware interfacing using LabVIEW graphical programming.
Grading status: Letter grade.

APPL 420. Introduction to Polymer Chemistry. 3 Credits.
Chemical structure and nomenclature of macromolecules, synthesis of polymers, characteristic polymer properties.
Requisites: Prerequisite, CHEM 261 or 261H; pre- or corequisites, CHEM 262 or 262H, and 262L or 263L.
Grading status: Letter grade
Same as: CHEM 420.

APPL 421. Synthesis of Polymers. 3 Credits.
Synthesis and reactions of polymers; various polymerization techniques.
Requisites: Prerequisites, CHEM 251 and 262 or 262H.
Grading status: Letter grade
Same as: CHEM 421.

APPL 422. Physical Chemistry of Polymers. 3 Credits.
Polymerization and characterization of macromolecules in solution.
Requisites: Prerequisites, CHEM 420 and 481.
Grading status: Letter grade
Same as: CHEM 422.

APPL 423. Intermediate Polymer Chemistry. 3 Credits.
Polymer dynamics, networks and gels.
Requisites: Prerequisite, CHEM 422.
Grading status: Letter grade
Same as: CHEM 423.

APPL 470. Fundamentals of Materials Science. 3 Credits.
Prerequisite, CHEM 482 or PHYS 117 or 119. mechanical properties of solids, thermal properties of materials, phase equilibria.
Requisites: prerequisite, PHYS 128 and pre- or corequisite, PHYS 441.
Grading status: Letter grade
Same as: CHEM 470.

APPL 472. Chemistry and Physics of Electronic Materials Processing. 3 Credits.
Prerequisite, PHYS 441. Permission of the instructor. A survey of materials processing and characterization used in fabricating microelectronic devices. Crystal growth, thin film deposition and etching, and microlithography.
Requisites: Prerequisite, CHEM 482 or PHYS 117 or 119.
Grading status: Letter grade
Same as: PHYS 472, CHEM 472.

APPL 473. Chemistry and Physics of Surfaces. 3 Credits.
The structural and energetic nature of surface states and sites, experimental surface measurements, reactions on surfaces including bonding to surfaces and adsorption, interfaces.
Requisites: Prerequisite, CHEM 470.
Grading status: Letter grade
Same as: CHEM 473.

APPL 490. Special Topics. 3 Credits.
Topics vary from semester to semester.
Repeat rules: May be repeated for credit; may be repeated in the same term for different topics; 12 total credits. 4 total completions.
Grading status: Letter grade.

APPL 491L. Materials Laboratory I. 2 Credits.
Structure determination and measurement of the optical, electrical, and magnetic properties of solids.
Requisites: Prerequisites, APPL 470 and PHYS 351.
Grading status: Letter grade
Same as: PHYS 491L.
APPL 492L. Materials Laboratory II. 2 Credits.
Continuation of PHYS 491L with emphasis on low- and high-temperature behavior, the physical and chemical behavior of lattice imperfections and amorphous materials, and the nature of radiation damage.
Requisites: Prerequisite, APPL 491L or PHYS 491L.
Grading status: Letter grade
Same as: PHYS 492L.

APPL 520L. Polymer Chemistry Laboratory. 2 Credits.
Various polymerization techniques and characterization methods. One four-hour laboratory each week.
Requisites: Pre- or corequisite, CHEM 420 or 421 or 425.
Grading status: Letter grade
Same as: CHEM 520L.

APPL 573. Introductory Solid State Physics. 3 Credits.
Crystal symmetry, types of crystalline solids; electron and mechanical waves in crystals, electrical and magnetic properties of solids, semiconductors; low temperature phenomena; imperfections in nearly perfect crystals.
Requisites: Prerequisite, PHYS 321; permission of the instructor for students lacking the prerequisite.
Grading status: Letter grade
Same as: PHYS 573.

MTSC
Advanced Undergraduate and Graduate-level Courses

MTSC 615. Structure of Solids. 3 Credits.
Crystallography, reciprocal lattices, Bloch waves, band structure, electronic wave functions, phonons, thermal expansion. Superlattice structures, including liquid crystals. Overview of properties of ceramic, amorphous, polymeric, and composite materials.
Grading status: Letter grade

Graduate-level Courses

MTSC 715. Visualization in the Sciences. 3 Credits.
Computational visualization applied in the natural sciences. For both computer science and natural science students. Available techniques and their characteristics, based on human perception, using software visualization toolkits. Project course.
Grading status: Letter grade
Same as: COMP 715, PHYS 715.

MTSC 720. Materials Fabrication. 3 Credits.
Permission of the department. Introduction to materials fabrication and characterization techniques. Includes single crystal growth, thin film deposition, synthesis of quantum dots and nanotubes/nanowires, dielectric and electron emissive materials, nanocomposites, bioceramics, and energy storage materials.
Grading status: Letter grade.

MTSC 730. Statistical Thermodynamics. 3 Credits.
Grading status: Letter grade.

MTSC 735. Techniques in Materials Science. 3 Credits.
Permission of the department. Lecture and laboratory in materials analysis techniques, including microscopy, X-ray diffraction and fluorescence, magnetic resonance, thermal analysis, XPS, channeling and RBS, mechanical properties, optical spectroscopy.
Repeat rules: May be repeated for credit.
Grading status: Letter grade.

MTSC 740. Advanced Biomaterials. 3 Credits.
Medical or dental implants or explants are highlighted from textbooks, scientific literature, and personal accounts.
Requisites: Prerequisite, BMME 510; Permission of the instructor for students lacking the prerequisite.
Grading status: Letter grade
Same as: BMME 740.

MTSC 745. Chemistry of Biomaterials. 3 Credits.
Focuses on the chemistry and chemical structure-function relationships of soft synthetic biological materials. Topics include chemistry of proteins, peptides, nucleic acids, polysaccharides and lipids, and their incorporation into biomaterials and biosensors; enzymatic reactions; chemical modification of organic and inorganic surfaces using self-assembled monolayer chemistries, bioconjugation chemistries, synthesis of nanoparticles and their application as sensors, application of biological materials for logic operations, fundamentals of supramolecular chemistry.
Grading status: Letter grade.

MTSC 750. Kinetics, Diffusion, and Phase Transitions of Materials. 3 Credits.
Grading status: Letter grade.

MTSC 755. Polymer Processing and Properties. 3 Credits.
How does one process ultrahigh molecular weight polyethylene into ultra-strong fibers or how would you design a polymer shape-memory actuator? Polymer chemistry is important but equally important is the way how polymers are processed. In this course we will discuss the relationship between polymer chemistry, processing and the final, after processing, properties. We will discuss different processing methods that are currently in use) and which parameters play a role in controlling the final properties.
Grading status: Letter grade.

MTSC 760. Complex Fluids: Theory and Applications. 3 Credits.
Complex fluids are materials we encounter everyday such as pastes, gels, foams, blood, and tissue, yet ones that cannot be categorized within the traditional three states of matter (solid/gas/liquid). In this course, we introduce the main physical and mathematical concepts of the continuum mechanics of complex fluids and follow with microscopic approaches. The course is designed to focus on both theory and applications with hands-on activities and examples.
Grading status: Letter grade.
MTSC 765. Electronic Materials and Devices - Organic and Inorganic. 3 Credits.
The course introduces the electronic and optical processes in organic molecules and polymers that govern the behavior of practical organic optoelectronic devices. The course begins with an overview of fundamental science of electronic materials and devices. We then discuss their optoelectronic properties of organic molecules, including topics from photophysics, charge transport and injection. Emphasis will be equally placed on the use of both inorganic and organic electronic materials in organic electronic devices.
Grading status: Letter grade.

MTSC 780. Advanced Materials Science. 3 Credits.
This course covers the physical fundamentals of material science with an in-depth discussion of structure formation in soft and hard materials and how structure determines material mechanical, electrical, thermal, and optical properties. Topics include amorphous and crystal structures, defects, dislocation theory, thermodynamics and phase diagrams, diffusion, interfaces and microstructures, solidification, and theory of phase transformation. Special emphasis will be on the structure-property relationships of (bio)polymers, (nano)composites, and their structure property relationships.
Grading status: Letter grade.

MTSC 810. Device Physics and Electronic Properties of Solids. 3 Credits.
Survey of crystal structure, bandstructure, transport. Overview of FETs, heterostructures, light emission, dissipation, noise, integrated circuits, solar cells, and ceramics. Emphasis on physical sources of device behavior.
Requisites: Prerequisites, APPL 470 or PHYS 573, MTSC 615, and 730; permission of the instructor for students lacking the prerequisites.
Grading status: Letter grade.

MTSC 820. Optical Properties of Solids. 3 Credits.
Reflection, waveguides, nonlinear optics, optical switching, photorefraction, optical storage. Optical coupling to electronic states, device applications, optical computing.
Requisites: Prerequisites, APPL 470 or PHYS 573, and PHYS 415; permission of the instructor for students lacking the prerequisites.
Grading status: Letter grade.

MTSC 830. Ion-Solid Interactions. 3 Credits.
Interatomic potentials, range distribution, radiation damage, annealing, secondary defects, analytical techniques, silicon-based devices, implantation in compound semiconductors, and buried layer synthesis. Ion implantation in metals, ceramics, polymers, and biomaterials.
Requisites: Prerequisite, APPL 470 or PHYS 573; permission of the instructor for students lacking the prerequisite.
Grading status: Letter grade.

MTSC 840. New Technologies and Device Architecture. 3 Credits.
Requisites: Prerequisites, APPL 470 or PHYS 573, MTSC 615, and 730; permission of the instructor for students lacking the prerequisites.
Grading status: Letter grade.

MTSC 871. Solid State Physics. 3 Credits.
Equivalent experience for students lacking the prerequisite. Topics considered include those of PHYS 573, but at a more advanced level, and in addition a detailed discussion of the interaction of waves (electromagnetic, elastic, and electron waves) with periodic structures, e.g., X-ray diffraction, phonons, band theory of metals and semiconductors.
Requisites: Prerequisite, PHYS 321.
Grading status: Letter grade
Same as: PHYS 871.

MTSC 872. Solid State Physics. 3 Credits.
Topics considered include those of PHYS 573, but at a more advanced level, and in addition a detailed discussion of the interaction of waves (electromagnetic, elastic, and electron waves) with periodic structures, e.g., X-ray diffraction, phonons, band theory of metals and semiconductors.
Requisites: Prerequisite, PHYS 321.
Grading status: Letter grade
Same as: PHYS 872.

MTSC 891. Special Topics in Material Science. 1-3 Credits.
Permission of the department. Current topics in materials science, including electronic and optical materials, polymers, and biomaterials.
Repeat rules: May be repeated for credit; may be repeated in the same term for different topics.
Grading status: Letter grade.

MTSC 992. Master’s (Non-Thesis). 3 Credits.
MTSC 993. Master's Research and Thesis. 3 Credits.
Permission of the department.
Repeat rules: May be repeated for credit.

MTSC 994. Doctoral Research and Dissertation. 3 Credits.
Permission of the department.
Repeat rules: May be repeated for credit.