Norfolk State University

SCHOOL OF SCIENCE AND TECHNOLOGY

Ph.D. Program in Materials Science & Engineering

Center for Materials Research

NORFOLK STATE UNIVERSITY

SCHOOL OF SCIENCE AND TECHNOLOGY

Ph.D. Program in Materials Science and Engineering
Dr. Suely M. Black, CMR Education Hub Director
(757) 823-8403

The Ph.D. in Materials Science and Engineering (MSE) is an interdisciplinary program housed in the Department of Physics. Persons holding baccalaureate or Master of Science degrees in chemistry, physics, materials science, electrical, chemical, or optical engineering, or related disciplines are eligible for admission.

The Ph.D. program addresses the critical technical needs of industry, academia, and government laboratories in the Commonwealth and the nation for scientific and engineering leadership in the area of advanced nano-structured materials and engineering. The program will prepare highly trained technical professionals in the area of nano-structured materials science and engineering for the next generation photonic, electronic, magnetic materials and devices, and for producing renewable clean energy generation.

The Materials Science and Engineering program at Norfolk State University prepares students for careers in industry, federal or private research laboratories, and academia. The program transitions students from physical sciences, engineering and related fields into the discipline of materials with special nano-structures and properties, broadening their professional opportunities. The thesis research component of the program is typically coordinated through the Center for Materials Research. However, research may also be conducted off campus through special programs at federal research facilities such as NASA Langley Research Center or Los Alamos National Laboratory, with prior approval of the thesis advisor.

The MSE program is designed to provide students with fundamental knowledge, analytical skills, and research experience necessary to contribute significantly to federal and commercial research efforts in the forefront of Materials Science. Therefore, the curriculum includes an overview of MSE and its current research areas, and offers an in-depth study of advanced materials synthesis, characterization of macroscopic and microscopic physical properties, theoretical and computational modeling, and device engineering.

The curriculum of the proposed program features technical core courses, professional development courses, core elective courses, additional elective courses, research, and a dissertation. The technical core courses establish baseline knowledge that brings students with diverse undergraduate background to a fundamental understanding of their new discipline. These courses impart a set of fundamental knowledge and skills to students with baccalaureate degrees in chemistry, physics, electrical engineering and related disciplines; and consequently, provide a new intellectual identity to those involved in the study and preparation of advanced materials. Students may also enroll in a range of advanced Materials Science electives to prepare for the interdisciplinary needs of their thesis research. This additional coursework is selected in

consultation with the student's advisor. The professional development courses grant unique preparation to strengthen communication skills, and involve post-graduation planning and career-oriented training.

The program for students entering with a B.S. degree consists of 9 credit hours of technical core courses, 3 hours of professional development courses, 12 hours of core electives selected from a group of core electives, 9 credit hours of research, a minimum of 6 (or more) hours of additional elective courses, 27 credit hours of Ph.D. research, and 9 credit hours for preparation and oral defense of the dissertation. A minimum of 75 credit hours must be taken at NSU. See the sample curriculum on page 11.

The program for students who enter the program after completion of a M.S. in Materials Science, from NSU or any other accredited physical science or engineering program, consists of a minimum of 3 hours of professional development courses, 6 hours of research and 9 hours in additional elective courses, 27 credit hours of Ph.D. research, and 9 credit hours for preparation and oral defense of the dissertation. A minimum of 54 credit hours must be taken at NSU. See the sample curriculum on page 13.

The dissertation research component of the program will be coordinated through the Center for Materials Research. However, research may also be conducted on-campus through the Department of Computer Science or the Department of Engineering and off-campus through special programs at federal research facilities such as NASA Langley Research Center, NASA Glenn Research Center, the Thomas Jefferson Laboratory, or at other research partner organizations with prior approval of the thesis advisor and mentoring committee. All research conducted by doctoral students will be supervised by faculty teaching in the doctoral program and serving on dissertation committees.

All general policies and procedures of the Norfolk State University Graduate Studies Office are in effect, except those that are superceded by the following specific policies of the M.S. in Materials Science program. The program is governed by the Graduate Committee, which meets at least three times annually. Between meetings, the program is administered by the CMR Education Hub Director. The Hub Director also provides academic advising for graduate students.

ADMISSION

The requirements for admission to the Ph.D. Program in Materials Science and Engineering are as follows:

1. a bachelor's degree in chemistry, physics, materials science, engineering or a related field from a regionally accredited institution and have a 3.0 grade point average on a 4.0 scale.

2. Submission of a complete application including the following:

   a) Completed Application Forms
   b) Application Fee

c) Statement of Purpose of at least 500 words explaining how the program will advance your career goals
d) Updated Resume
e) GRE Scores
f) At least three Letters of Recommendation from persons who are qualified to evaluate your academic and research experience
g) Official Transcripts
h) TOEFL scores for international applicants.

Admission to the graduate program in Materials Science and Engineering may be regular or conditional. For regular admission, applicants must have a bachelor's degree in chemistry, physics, materials science, engineering or a related field from a regionally accredited institution and have a 3.0 grade point average on a 4.0 scale. Equivalent degrees from foreign institutions may also be accepted, with the additional requirement of a minimum computerized TOEFL score of 220 for non-native English speakers. Waiver of TOEFL scores may be granted if applicant fulfills special requirements.

Conditional admission may be granted to applicants who do not meet the criteria for regular admission. Upon the completion of nine (9) or more graduate credits with a 3.0 or better, the student may petition the Materials Science Graduate Committee for conversion from conditional to regular status.

Non-degree status may be granted to a person who has a baccalaureate degree in an appropriate field and who wishes to take particular courses without pursuing a graduate degree. The courses may be taken on a credit or a non-credit basis. Generally, a maximum of nine credit hours with a 3.0 average or above may be applied toward degree requirements if the non-degree student is subsequently admitted to the Ph.D. in Materials Science and Engineering program. Non-degree students are ineligible for fellowships or assistantships administered by the Graduate Committee.

The program for students entering with a B.S. degree consists of 9 credit hours of technical core courses, 3 hours of professional development courses, 12 hours of core electives selected from a group of core electives, 9 credit hours of research, a minimum of 6 (or more) hours of additional elective courses, 27 credit hours of Ph.D. research, and 9 credit hours for preparation and oral defense of the dissertation.

TRANSFER CREDITS

The program for students who enter the program after completion of a M.S. in Materials Science or related disciplines,, from NSU or any other accredited physical science or engineering program, consists of a minimum of 3 hours of professional development courses, 6 hours of research and 9 hours in additional elective courses, 27 credit hours of Ph.D. research, and 9 credit hours for preparation and oral defense of the dissertation. A minimum of 54 credit hours must be taken at NSU. Transfer students should consult the Program Coordinator for further information regarding transfer credits.

RESIDENCE REQUIREMENTS

Candidates for the Ph.D. in Materials Science and Engineering must be enrolled at Norfolk State University for a minimum of six semesters prior to graduation. Thesis research must be conducted under the supervision of a regular or adjunct NSU faculty member approved by the Materials Science and Engineering Graduate Committee.

RE-ADMISSION

A student planning to interrupt his/her approved plan of study should consult his/her advisor. In some cases, continuous registration may be required by the Graduate Studies Office, or the filing of a "continuous matriculation" form may be required. Re-admission to the program after an absence of a semester or longer is not automatic and requires the filing of an admission application.

MINIMUM DEGREE REQUIREMENTS

All students are required to complete a total of 75 credit hours, including research and thesis preparation credits.

This requirement includes the following 12 semester hours of core courses:

Professional Development
MSE 600 Materials Science Seminar I
MSE 601 Materials Science Seminar II
MSE 605 Ethics of Scientific Research and Professional Preparation and Conduct

Technical
MSE 530 Introduction to Materials Science
MSE 533 Chemistry of Modern Materials and Polymers
MSE 535 Electronic and Photonic Materials Engineering (3 hrs)

In addition to the 12 required core courses, students must complete six (6)) hours of approved technical core electives out of the following:

CHM 545 Mathematical Methods for Materials Science
PHY 580 Quantum Mechanics for Materials Science
MSE 575 Basic Instrumentation for Materials Science
MSE 635 Optical Materials
MSE 607 Materials for Nanotechnology
MSE 609 Introduction to Computational Materials Science
MSE 580 Advanced Organic Synthesis and Characterization

Students also must select six (6) credits of technical electives, depending on their research interest among the following:

CHM 573 Advanced Inorganic Chemistry
CHM 633 Molecular Dynamics
CHM 663 Atomic and Molecular Spectroscopy
PHY 653 Solid State Physics
PHY 675 Electricity and Magnetism
MSE 660 Organic Optoelectronic Materials and Devices
MSE 704 Thin Film Phenomena
MSE 707 Materials for Nanotechnology
OEN 630 Opto-electronic Devices
OEN 650 Microelectromechanical Systems
OEN 661 Optics and Lasers
MSE 703 Materials and Devices for Solar Energy Conversion

Finally, all students are required to complete 45 credits of research and dissertation course work. A dissertation committee, composed of the student's advisor, three other Materials Science and Engineering faculty members and a fifth committee member outside of Materials Science Engineering advises the students through his/her research work. The dissertation is defended in an open forum as the Final Dissertation Defense. After the delivery and approval of a finalized dissertation manuscript the Ph.D. degree will be awarded.

ACADEMIC STANDARDS

In order to graduate, students must complete the curriculum with a minimum 3.0 grade point average on a 4.0 scale. Each student's progress is reviewed at the end of each semester by the Education Hub Director.

The system of grading is as follows:

Grade	Grade Points	Interpretation
A	4.00	Excellent
A-	3.70	Excellent
B+	3.30	Good
B	3.00	Satisfactory
B-	2.70	Fair
C+ or below	Unsatisfactory (course must be repeated to fulfill graduation requirement)	

Students with a GPA of 3.00 or higher are considered to be in good academic standing. In order to receive teaching or research assistantships, students must generally be in good academic standing, and be making normal progress toward degree completion.

Failure to maintain the required 3.0 GPA results in probationary status or suspension from the program as outlined below.

Students on probationary status generally do not receive renewals of teaching or research assistantships and are not eligible for tuition grants. Students who were admitted on a provisional basis will not be changed to regular status unless the required 3.0 GPA is obtained.

Students placed on suspension are not permitted to enroll in additional courses in the Materials Science program until reinstatement is granted by the Materials Science Graduate Committee. The request for reinstatement should include explanation of mitigating circumstances surrounding past academic performance and/or justification for predicting future success in the program if reinstatement is granted. The Materials Science Graduate Committee will review the request and may interview the suspended student prior to making a final recommendation. The Committee may require successful completion of relevant undergraduate courses as a precondition for reinstatement.

DESCRIPTION OF COURSES

CHM 545 **Mathematical Methods (Three Credits)**
This course deals with application of series solutions of differential equations, vector analysis, determinants and matrices, complex variables, and integral transforms to problems encountered in the physical sciences.

CHM 573 **Advanced Inorganic Chemistry (Three Credits)**
This course examines the principles of structure, bonding, and reactivity patterns of inorganic compounds. The application of group theory to chemistry and spectroscopy, especially vibrational and electronic structure of metal complexes and crystals, is also examined.

MSE 530 **Materials Science (Three Credits)**
This course presents basic knowledge of the internal structure, properties, processing, and characterization of materials, including metals, ceramics, inorganic composites, and “smart” materials.

MSE 533 **Polymers and Polymer-Based Composite Materials (Three Credits)**
This course deals with general concepts about polymers and polymeric materials/composites, their compositions, chemical structure, synthesis and fabrication, characterization and properties.

MSE 535 **Electronic and Photonic Materials (Three Credits)**
This course deals with the internal structure, chemistry and physics of semiconductors, magnetic and photonic materials as related to their electronic and optical properties, as well as their applications. The course also focuses on how electronic materials are produced, and how to control processing to achieve desired materials performance.

MSE 575 **Instrumentation for Materials Science (Three Credits)**
This course presents scientific data manipulation and visualization with IDL; data collection and data analysis with the LabView Interface; powder x-ray diffraction technique.

MSE 600 **Materials Science and Engineering Seminar I (Three Credits)**
This course exposes students to the most recent research developments in the areas of materials science and engineering. Students attend weekly seminars, delivered by local and invited scientists and engineers, who present results of projects carried in their research groups.

MSE 601 **Materials Science and Engineering Seminar II (Three Credits)**
This course exposes students to the most recent research developments in the areas of materials science and engineering. Students attend weekly seminars, delivered by local and invited scientists and engineers, who present results of projects carried in their research groups

MSE 605 **Ethics of Scientific Research and Professional Preparation and Conduct (One Credits)**
This is a core professional development course, designed for science and engineering graduate students. Students will learn about ethics in the workplace, receive guidance in the selection of and application to job positions in materials science and engineering, as well as improve their skills such as in written and oral communication.

MSE 607 **Materials for Nanotechnology (Three Credits)**
This course provides a broad overview of the entire arena of nanotechnology including phenomena specific for nanoparticle or nanostructured systems, as well as their modern and future applications. The topics include: characterization and fabrication methods in nanoscale, properties of materials as a function of size, review of nanocrystals, quantum dots, nanophotonic structures, nanomagnets and brief introduction to the principles of quantum computing.

MSE 609 **Introduction to Computational Materials Science (Three Credits)**
This course provides graduate students with basic skills in computational materials science. The course includes topics of quantum theory related to the microscopic structure of atoms, molecules, polymers, and solids, as well as overview of numerical modeling of materials properties, predictions, and analysis.

MSE 635 **Optical Materials (Three Credits)**
The course relates optical behavior and its underlying processes to the chemical, physical, and microstructural properties of the materials so that students gain insight into the kinds of materials, engineering and processing

conditions that are required to produce materials exhibiting a desired optical property.

CHM 633 **Molecular Dynamics (Three Credits)**
This course examines modern concepts in reaction-transport phenomena, transition state theory, and reaction dynamics. Experimental techniques and physical models for reactivity at a microscopic level are discussed.

CHM 663 **Atomic and Molecular Spectroscopy (Three Credits)**
This course deals with the study of the interaction of radiation with matter. The application of quantum mechanics for the spectroscopic determination of the rotational, vibrational, and electronic structure of matter are examined.

MSE 660 **Organic Optoelectronic Materials and Devices (Three Credits)**
This course covers the basic knowledge, concepts and current status of organic/polymeric electronic and optoelectronic (OE) materials and devices. From fundamentals of π electron conjugated organic and polymeric materials structures, synthesis, to basic principles, architectures, and functions of organic/polymeric electronic and OE devices including, but not limited to, field effect transistors (FETs), light emitting diodes (LEDs), solar cells, electro-optic modulators, optical-switching materials and devices, photorefractive materials and devices, single molecule OE devices, artificial Muscles, spintronic and supramolecular OE materials and devices, *etc*.

MSE 680 **Advanced Organic Synthesis I (Three Credits)**
This course will cover essential synthetic and characterization methodologies of complex organic molecules and polymers, particularly the conjugated semiconducting and conducting molecules and polymers relevant to supramolecular 'plastic' electronic and optoelectronic applications. The course will first provide a brief overview of important and relevant organic reactions and mechanisms, it will then present advanced lab techniques and instrumentations, product purification and characterizations, including air-sensitive chemicals handling, vacuum distillation, sublimation, rotary evaporation, thin-layer chromatography, column chromatography, nuclear magnetic resonance spectroscopy (NMR), elemental analysis and mass spectrometry, thermal analysis (DSC/TGA), gel permeation chromatography (GPC) and HPLC, cyclic voltammetry (CV), UV-VIS spectrometry, luminescence spectrometry, FT-IR-Raman, *etc*

MSE 703 **Materials and Devices for Solar Energy Conversion (Three Credits)**
This course provides second year graduate students the fundamental knowledge, concepts, and current state of the art of inorganic and organic photovoltaic materials, devices, and their applications. It also covers basic knowledge on sustained renewable energy and environmental conservations. The course will present the principles, materials structures, devices

architectures, advantages and disadvantages of each materials and devices, problems, and approaches to improve.

MSE 704 **Thin Film Phenomena (Three Credits)**
This is a core elective course, taken by materials science and engineering doctoral students during their first or second year. Students will learn about critical issues on thin film processing, characterizations and possible device applications.

MSE 697 **Research I (Three Credits)**
Prerequisite: Permission of instructor
The Research I course is the first of a 3-semester research courses sequence. Students attend seminars and workshops on how to conduct, present and report research activities. Students are also expected to spend considerable time in their research laboratories or in research related activities - between 10 and 15 hours a week. The students must work closely with their research advisor to ensure progress in the course.

MSE 698 **Research II (Three Credits)**
Prerequisite: Permission of instructor
The Research II course is the second of a 3-semester research courses sequence. Students attend seminars and workshops on how to conduct, present and report research activities. Students are also expected to spend considerable time in their research laboratories or in research related activities - between 10 and 15 hours a week. The students must work closely with their research advisor to ensure progress in the course.

MSE 699 **Research III (Three Credits)**
Prerequisite: Permission of instructor
The Research III course is the third of a 3-semester research courses sequence. Students attend seminars and workshops on how to conduct, present and report research activities. Students are also expected to spend considerable time in their research laboratories or in research related activities - between 10 and 15 hours a week. The students must work closely with their research advisor to ensure progress in the course.

MSE 750 **Continuing Registration (One Credit)**

MSE 897 **Ph.D. Research I (Nine Credits)**
Prerequisite: Permission of instructor
This course provides Ph.D. in the Materials Science and Engineering program academic credit for working solely in the development of their Ph.D. thesis research project. Students are expected to spend considerable time in their research laboratories or in research related activities - between 35 and 40 hours a week – and consult with their research advisor often to ensure progress in the course towards completion of their doctoral research project.

MSE 898 **Ph.D. Research II (Nine Credits)**

Prerequisite: Permission of instructor

This course provides Ph.D. in the Materials Science and Engineering program academic credit for working solely in the development of their Ph.D. thesis research project. Students are expected to spend considerable time in their research laboratories or in research related activities - between 35 and 40 hours a week – and consult with their research advisor often to ensure progress in the course towards completion of their doctoral research project.

MSE 899 **Ph.D. Research III (Nine Credits)**

Prerequisite: Permission of instructor

This course provides Ph.D. in the Materials Science and Engineering program academic credit for working solely in the development of their Ph.D. thesis research project. Students are expected to spend considerable time in their research laboratories or in research related activities - between 35 and 40 hours a week – and consult with their research advisor often to ensure progress in the course towards completion of their doctoral research project.

MSE 900 **Ph.D. Dissertation (Nine Credits)**

Prerequisite: Permission of instructor

This course provides guidance for students who are in the final phase of their doctoral studies. Students are expected to spend considerable time preparing their dissertation manuscript and oral defense. Students must work closely with their research advisors to ensure progress in the dissertation writing, and thesis oral defense preparation.

MSE 999 **Continuing Registration (No Credit)**

Prerequisite: Permission of instructor

PHY 580 **Quantum Mechanics for Materials Scientists (Three Credits)**

This course covers basic principles, the Schroedinger equation, wave functions, representation of dynamical variables as operators or matrices; bound and continuum states in one-dimensional systems; bound states in central potentials; hydrogen atoms; Perturbation Theory; the interaction of electromagnetic radiation with atomic systems; rotations and angular momentum and applications to solid-state systems.

PHY 653 **Solid State Physics (Three Credits)**

This course covers mechanical, thermal, and electric properties of solids; crystal structure; Band Theory; semiconductors; phonons and transport phenomena.

PHY 675 **Electricity and Magnetism (Three Credits)**

This course covers the development of Maxwell's equations; Conservation Laws; problems in electrostatics and magnetostatics; time-dependent solutions of Maxwell's equations; motion of particles in electromagnetic fields; plane waves in dielectric and conductive media; dipole and quadrupole radiation from nonrelativistic systems; Fourier analysis of radiation field and photons, and scattering and diffraction of electromagnetic waves.

Ph.D. IN MATERIALS SCIENCE AND ENGINEERING

Sample Curriculum

1st Year Fall Coursework		Credit Hours
MSE 530	Materials Science	3
CHM 545	Mathematical Methods	3
MSE 533	Polymers and Polymer-Based Composite Materials	3
MSE 600	Materials Science Seminar I	3

Other Tasks

- Meet with faculty and students to identify set of research interests
- Select research advisor
- Complete attainment exams in Chemistry, Physics, and Math Methods

1st Year Spring Coursework		Credit Hours
MSE 680	Advanced Organic Synthesis and Characterization	3
MSE 535	Electronic and Photonic Materials Engineering	3
MSE 601	Materials Science Seminar II	3
MSE 697	Research I	9

Other Tasks

- Submit program of study for thesis project (listing of courses needed)

2nd Year Fall Coursework		Credit Hours
MSE 605	Ethics of Scientific Research & Professional Conduct	3
MSE 575	Instrumentation for Materials Science	3
MSE 635	Optical Materials	3
MSE 698	Research II	9

Other Tasks

- Initiate qualifying examination process – three exams based on the core

2nd Year Spring Coursework		Credit Hours
CHM 633	Molecular Dynamics	3
OEN 630	Opto-electronic Devices	3
MSE 699	Research III	9

Other Tasks

- Prepare and defend thesis proposal

3rd Year Fall Coursework		Credit Hours

MSE 897 Doctoral Research I 9

Other Tasks

- Submit thesis proposal
- Organize Thesis Advisory Committee (TAC)
- Complete Oral examination of thesis proposal
- Attain Full admission to Ph.D. candidacy; M.S. degree awarded

3rd Year Spring Coursework **Credit Hours**

MSE 898 Doctoral Research II 9

4th Year Fall Coursework **Credit Hours**

MSE 899 Doctoral Research III 9

Other Tasks

- 4th year review of progress with TAC

4th Year Spring Coursework **Credit Hours**

MSE 900 Doctoral Thesis 9

Other Tasks

- Prepare Ph.D. thesis
- Submit Ph.D. thesis to TAC
- Schedule and hold public defense of thesis defense
- Submit corrected Ph.D. Thesis