Vanderbilt

Interdisciplinary Program in Materials Science

SCHOOL OF ENGINEERING

contents

ABOUT THE PROGRAM

The Interdisciplinary Materials Science (IMS) program at Vanderbilt University offers a unique opportunity to design a master's or Ph.D. program that satisfies a graduate student's individual interests. With 37 full-time faculty members involved in the program and an individually customized curriculum, many options are available to students who desire an advanced materials science degree. Hands-on research opportunities are possible owing to the extensive infrastructure at Vanderbilt for materials processing and characterization. A long history of collaboration between the Vanderbilt IMS program and the Oak Ridge National Laboratory provides the graduate student with exposure to truly state-of-the-art equipment and interaction with world-class scientists. Competitive stipends are available for qualified students to provide for a comfortable financial setting during the IMS graduate degree program.

Materials advancements improve the standard and the quality of living. They are indeed the underpinning of the development of new technologies. In today's sophisticated and complicated climate, continued advancements in materials demand intimacy among a variety of disciplines. In recognition of this at Vanderbilt University, faculty members from chemistry, physics, materials engineering, chemical engineering, electrical engineering, mechanical engineering, and civil engineering have come together to form the IMS program. In this arena, there is extensive collaboration in both the teaching of and research in materials science.

VANDERBILT INSTITUTE OF NANOSCALE SCIENCE AND ENGINEERING

In addition to collaborative research that crosses boundaries of academic disciplines within Vanderbilt, the IMS program partners with the Vanderbilt Institute of Nanoscale Science and Engineering (VINSE). VINSE is a university institute focused on new science and technology based on nanoscale materials.

The institute carries out frontier science and technology by teaming locally and globally, and providing an environment where physicists, chemists, biologists, and engineers may collaboratively solve forefront problems and create new scientific understanding.

VINSE researchers inspire students by creating an atmosphere of excitement and creativity. It functions as an interdisciplinary center, eliminating traditional disciplinary boundaries and enabling a new paradigm for research and innovation.

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bio/medical

Nanoscience and nanotechnology hold great potential for revolutionary advances in biology and medicine. Vanderbilt researchers in the Interdisciplinary Materials Science program are creating new innovations through the use of nanoparticles for research, diagnostics, and therapy. David Wright studies how microbes create inorganic nanomaterials like silica and hemozin using bioinorganic chemistry. Todd Giorgio, David Cliffel, and Rick Haselton lead teams that develop and test novel therapeutic and diagnostic devices based on the unique properties of metal nanoparticles. Hak-Joon Sung focuses on polymeric biomaterials based chemical matrix engineering, cellular engineering, and tissue engineering. Craig Duvall creates stimuli-responsive, bio-inspired "smart" polymers for nano-carrier and hydrogel drug delivery. Similarly, Eva Harth's group has created novel polymeric nanoparticles that significantly improve the results of cancer therapies in vivo. The Biomolecular Nanostructures Laboratory and the Nanocrystal Fabrication Laboratories of the Vanderbilt Institute for Nanoscale Science and Engineering provide critical space and instrumentation for collaborations that bring together these investigators to advance promise of nanotechnology for addressing medical needs.

David Cliffel

Associate Professor of Chemistry; Director, VINSE Biomolecular Nanostructures Facility

Research interests: Fundamentals of electron transfer reactions in nanometer scale systems, monitoring metabolic activity of live cell populations using electrochemistry and in-situ surface analytical techniques

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Jon Edd

Assistant Professor of Mechanical Engineering

Research interests: Inertial and drop-based microfluidics (BioMEMS), fluid mechanics, heat transfer, non-equilibrium thermodynamics, cryopreservation and cryosurgery, electrical impedance tomography, and irreversible electroporation

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Craig Duvall

Assistant Professor of Biomedical Engineering

Research interests: Drug delivery; regenerative medicine; RAFT polymerization; stimuli responsive polymers; intracellular delivery of biomacromolecular drugs; development of in vivo vascular contrast agents

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Todd Giorgio

Professor and Chair of Biomedical Engineering; Associate Professor of Chemical and Biomolecular Engineering

Research interests: Protease-responsive biosensors, theranostic systems for combined imaging and drug delivery, gene and siRNA delivery, phage display for discovery of peptides for drug and gene delivery applications

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Scott Guelcher

Assistant Professor of Chemical and Biomolecular Engineering

Research interests: Biomaterials; bone tissue engineering; polymer synthesis and characterization; drug and gene delivery

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Frederick Haselton

Professor of Biomedical Engineering

Research interests: Coffee ring stain diagnostics for malaria; development of DNA logic operations for viral diagnostics; multispectral quantum dot-based retinal imaging; the role of Bves in the human cornea

Email: *rick.haselton@vanderbilt.edu*
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Kane Jennings

Professor of Chemical Engineering

Research interests: Molecular and surface engineering; polymer thin films; solar energy conversion; tribology; fuel cells

Email: *kane.g.jennings@vanderbilt.edu*
Website: che.vanderbilt.edu/index.php/faculty/71-g-kane-jennings

Charles Manning

Assistant Professor of Radiology and Radiological Sciences; Assistant Professor of Neurological Surgery; Assistant Professor of Biomedical Engineering

Research interests: Molecular imaging, chemistry, small-molecule discovery, therapeutic efficacy screening, clinical trial modeling, imaging probe development, imaging validation

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Hak-Joon Sung

Assistant Professor of Biomedical Engineering

Research interests: Biomaterials and biointerface for vascular and stem cell engineering

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David Wright

Associate Professor of Chemistry; Associate Professor of Pediatrics

Research interests: Design, synthesis, and characterization of organic templates capable of mediating the growth of biologically important biominerals

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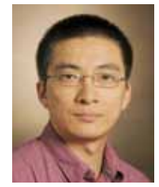

Qi Zhang

Assistant Professor of Pharmacology

Research interests: Trafficking and recycling of synaptic vesicles; exo-/endocytosis in dopaminergic synapses; vesicle retrieval and Alzheimer's disease

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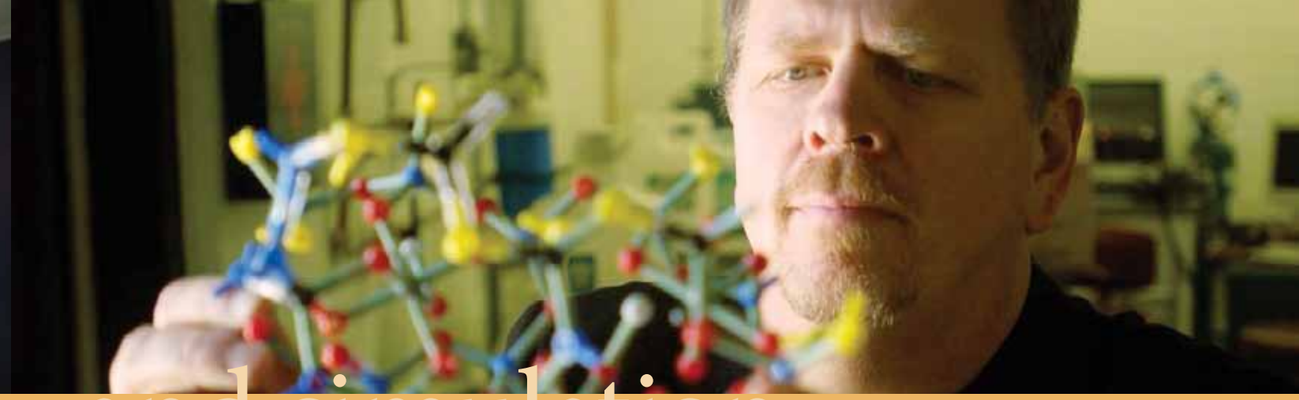

theory, modeling, and simulation

A hierarchy of state-of-the-art computational approaches and theoretical models, ranging from molecular dynamics of atoms to time-dependent density functional theory simulation of electrons and ions, are used to describe, understand, and design materials. Modeling and simulation are indispensable tools in nanoscale science and engineering and a major focus area in the materials program at Vanderbilt. Using these tools, researchers find links between the electronic, optical, mechanical, and magnetic properties and the size, shape, topology, and composition of nanostructures to further the impact of nanoscale research on technology and society.

For example, consider the vast design space for exotic thermoelectric materials, which span the range of semiconductors including compound semiconductors. Then add the complexity of tuning the transport properties by nanostructuring these materials as superlattices, nanocrystalline composites, and skutterudites. Atomistic and quantum simulations help downselect promising materials based on fundamental physical quantities, and complex designs can be analyzed and optimized to help guide experimental investigations. Results of these types of studies have led to orders of magnitude improvement in performance, which promises to revolutionize how society collects, processes, and utilizes energy.

Research at Vanderbilt also focuses on detailed studies of hybrid organic-inorganic monolayers used to lubricate nanostructures, transport in quantum dots used for solid-state lighting, self-assembly of lipid bilayers used to understand cell transport properties, design of active cellulases used to increase the efficiency of bio-fuel processing, and much more.

Peter Cummings

John R. Hall Professor of Chemical and Biomolecular Engineering; Director, Nanomaterials Theory Institute, Oak Ridge National Laboratory

Research interests: Computational nanoscience and nanoengineering; molecular modeling of fluid and amorphous systems; parallel computing; cell-based models of cancer tumor growth

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Clare McCabe

Professor of Chemical and Biomolecular Engineering and Chemistry

Research interests: Molecular modeling of complex fluids and materials; biological self-assembly; molecular rheology and tribology; molecular theory and phase equilibria

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Kalman Varga

Assistant Professor of Physics

Research interests: Computational nanoscience, density functional theory, transport calculations, quantum Monte Carlo calculations, stochastic variational method, time dependent density functional theory, quantum dots, molecular dynamics simulations

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Greg Walker

Associate Professor of Mechanical Engineering; Director, Interdisciplinary Graduate Program in Materials Science

Research interests: Ultrasonic pyrometry, thermographic phosphor temperature measurement, nanoscale electrical and thermal transport modeling, energy conversion devices

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optics

Students and faculty in the optics group seek to understand how light interacts with matter and how this interaction can guide the development of materials with novel optical properties and functionalities. Research in the group is primarily focused on nanoscale materials in which reduced dimensionality offers new freedom to control light-matter interactions. Areas of concentration include: nanoporous materials for chem-bio sensing and hybrid silicon components for on-chip optical signal modulation (Weiss), ultrafast spectroscopy, phase-change materials, and plasmonics (Haglund), and metamaterials, reconfigurable photonic materials, and energy conversion (Valentine).

Given overlapping interests and complementary capabilities, collaborations both within and outside of the group are common, offering students a chance to work with faculty and fellow students from multiple disciplines. Members of the group frequently use the facilities of VINSE and the Center for Nanophase Materials Science at Oak Ridge National Laboratory, gaining valuable hands-on experience designing, fabricating, and characterizing nanoscale materials. The optics group provides students with research opportunities at the forefront of nanoscale optics, developing the next generation of materials and devices for controlling and harnessing the flow of light.

Richard Haglund
Professor of Physics; Director, VINSE Nano-Optics Facility

Research interests: Ultrafast and wavelength-selective laser interactions with materials; nanoscale nonlinear optics and nanoscale phase transitions; materials processing and analysis of materials using laser spectroscopy

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Jason Valentine
Assistant Professor of Mechanical Engineering and Electrical Engineering

Research interests: Optical metamaterials, transformation optics, nanophotonics, nanoimaging, active photonics, solar energy conversion, scalable 3D nanomanufacturing

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Kirill Bolotin
Assistant Professor of Physics

Research interests: Fractional quantum Hall effect and other correlated states of Dirac fermions in ultraclean grapheme; chemical synthesis of high-quality grapheme; nanoelectromechanical (NEMS) graphene resonators and their application as sensitive mass and force sensors; nanoscale magnetism

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Sharon Weiss
Associate Professor of Electrical Engineering; Associate Professor of Physics

Research interests: Photonics, biosensing, optical properties of materials, optoelectronic devices

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Yaqiong Xu
Assistant Professor of Physics and Electrical Engineering

Research interests: Nanoelectronics, optoelectronics, nanobiohybrids

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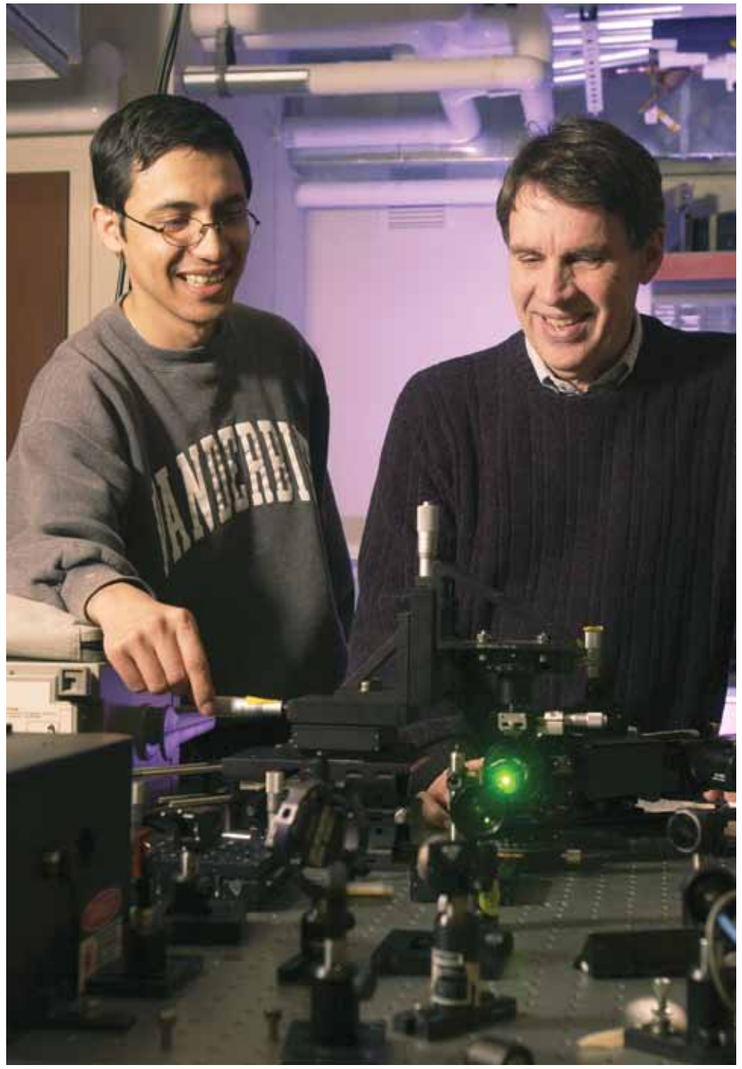

energy

Energy is the most pressing challenge facing America's prosperity and security in the coming century. Energy is also a global issue; solutions for clean energy must be found as growing economies expand and developing countries seek to improve their quality of life. A new NSF TN-SCORE block grant supports energy research at Vanderbilt. The work focuses on solar energy conversion, energy storage, and energy efficiency. Examples of research being conducted include novel approaches to fuel cells, the implementation of biological photosystems in biohybrid solar cells, graphene as a novel electrode material in solar cells, nanocrystal-sensitized solar cells, white-light emitting nanocrystals for energy efficient solid state lighting, and optical metamaterials for enhancing efficiency in solar cells.

James Dickerson

Associate Professor of Physics

Research interests: Electric field mediated deposition of nanocrystals and nanoparticulates into thin film structures (electrophoretic deposition) and the synthesis and characterization of novel nanocrystalline materials for luminescent display device applications and for magnetic and magneto-optical device applications

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Kane Jennings

Professor of Chemical Engineering

Research interests: Molecular and surface engineering; polymer thin films; solar energy conversion; tribology; fuel cells

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Weng Kang

Professor of Electrical Engineering; Professor of Computer Engineering; Professor of Materials Science and Engineering

Research interests: Electronic devices and sensors utilizing the emerging chemical vapor deposited CVD diamond technology as well as the traditional silicon technologies

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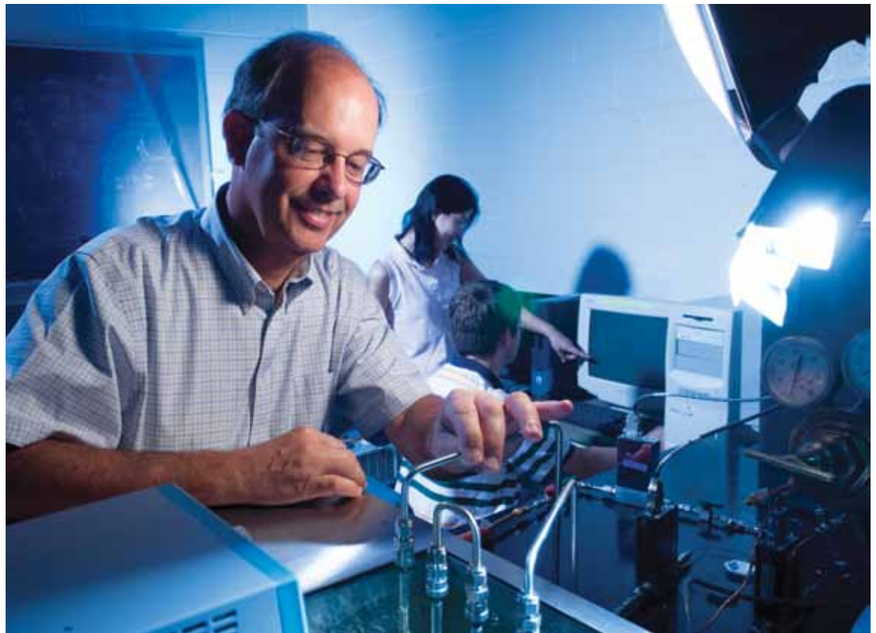

Douglas Levan

J. Lawrence Wilson Professor of Engineering; Professor of Chemical and Biomolecular Engineering

Research interests: Novel absorbent materials; absorption equilibria; mass transfer in nanoporous materials; adsorption and membrane processes

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Deyu Li

Associate Professor of Mechanical Engineering

Research interests: Micro/nanoscale energy and molecular transport phenomena, nanofabrication techniques, molecular dynamics and Monte Carlo simulation, micro/nanofluidics

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Bridget Rogers

Associate Professor of Chemical and Biomolecular Engineering; Director, VINSE Silicon Integration Facility

Research interests: Surfaces, interfaces, materials: processing, characterization, and applications in microelectronics, energy generation, and extreme environments

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Sandra Rosenthal

Jack and Pamela Egan Professor of Chemistry; Professor of Physics, Pharmacology, and Chemical and Biomolecular Engineering; Director, Vanderbilt Institute of Nanoscale Science and Engineering; Director, VINSE Nanocrystal Fabrication Facility

Research interests: Synthesis, characterization, surface modification, and ultrafast carrier dynamics of semiconductor nanocrystals for applications in biological imaging, photovoltaics, and solid state lighting

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Greg Walker

Associate Professor of Mechanical Engineering; Director, Interdisciplinary Graduate Program in Materials Science

Research interests: Electro-thermal simulation of semiconductor devices, microscale heat transfer and energy transport, microrefrigeration and energy conversion, MEMS, inverse and parameter estimation methods, heat flux measurement, scientific computational methods, software integration architectures

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semiconductors

Semiconductor science and technology are ubiquitous in modern civilization. It is also clear that spectacular new developments in the semiconductor area will continue to drive the global economy. Researchers at Vanderbilt are working at the forefront of this vibrant field involving semiconductor materials fabrication, characterization, and modification. Areas of emphasis include studies of semiconducting nanocrystals, a novel material whose optical properties and electronic structure may be tuned for light harvesting in photovoltaic devices, ultra-fast dynamics of carriers and phonons at surfaces and interfaces, and spin phenomena in semiconductor heterostructure systems. Additional research focus includes grapheme-based systems, effects of ionizing radiation on microelectronic devices and materials, nanoscale thin film and surface-interface science of semiconductor nanostructures, and radiation effects on semiconductor devices. Major research areas also include optical properties of materials at the nanoscale for applications in biosensing and light emitting diodes (LEDs), nonlinear laser interactions with nanostructured materials, microscale energy transport in semiconductor devices designed for energy conversion, and the synthesis of carbon nanotubes and graphene by chemical vapor deposition methods and characterization of their optoelectronic properties.

Kirill Bolotin

Assistant Professor of Physics

Research interests: Fractional quantum Hall effect and other correlated states of Dirac fermions in ultraclean grapheme; chemical synthesis of high-quality grapheme; nanoelectromechanical (NEMS) graphene resonators and their application as sensitive mass and force sensors; nanoscale magnetism

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Daniel Fleetwood

Olin H. Landreth Professor of Engineering; Professor and Chair of Electrical Engineering

Research interests: Effects of ionizing radiation on microelectronic devices and materials; defects, charge trapping, and radiation hardness in semiconductors; alternative dielectrics

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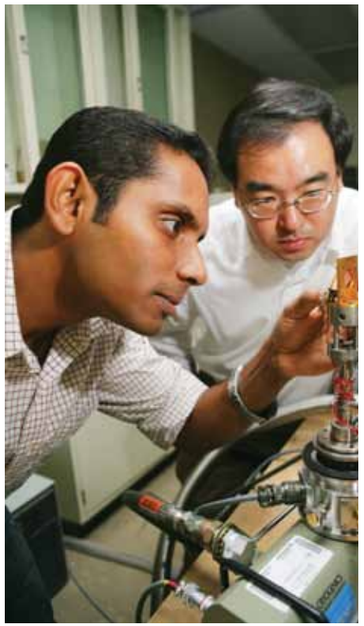

Anthony Hmelo

Research Associate Professor of Physics and Materials Science; Director, VINSE Core Laboratories

Research interests: Nanofabrication technology; RBS and VdG accelerator physics; diamond technology; containerless processing; acoustic, electron, photon, and ion beam methods for materials characterization and surface modification

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Deyu Li

Associate Professor of Mechanical Engineering

Research interests: Micro/nanoscale energy and molecular transport phenomena, nanofabrication techniques, molecular dynamics and Monte Carlo simulation, micro/nanofluidics

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Ronald Schrimpf

Orrin Henry Ingram Professor of Engineering; Professor of Electrical Engineering; Director, Institute for Space and Defense Electronics

Research interests: Semiconductor devices, particularly issues related to radiation effects and reliability

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Norman Tolk

Professor of Physics

Research interests: Experimental physics, dynamics of electronic processes at surfaces and interfaces, spintronics, atomic collision physics, quantum mechanical phase interference effects, and linear and nonlinear laser interactions with surface and interfaces

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materials research

Materials research involves constructing structure-property-processing relationships in order to develop new materials and optimize the performance of existing materials. These structure-property-processing relationships apply to all material classes including metals, ceramics, polymers, composites, and electronic materials and become increasingly important for materials at the nanoscale. The Vanderbilt Interdisciplinary Materials Science (IMS) faculty represents a diverse group of scientists with expertise in modeling and simulation (Pantelides), atomic scale materials characterization using electron microscopy (Wittig), chemical processing (Lukehart and Harth), and innovative development of new nanoscale materials systems (Laibinis and Sanchez). Many IMS faculty members have strong collaborations with the Oak Ridge National Laboratory (ORNL) that provide access to some of the fastest computing systems in the world, sub-angstrom resolution aberration-corrected electron microscopy facilities, and world-class staff scientists. Vanderbilt offers graduate students outstanding opportunities to perform cutting edge research using state-of-the-art facilities by combining the resources at Vanderbilt with opportunities to perform research at ORNL that include the Center for Nanophase Materials Science.

Timothy Hanusa
Professor of Chemistry

Research interests:
Inorganic chemistry, molecular chemistry of the main-group metals, use of sterically bulky allyl ligands in catalysis and the study of non-covalent interactions, symmetry effects on the magnetic properties of transition metal complexes

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Eva Harth
Associate Professor of Chemistry; Associate Professor of Pharmacology

Research interests:
Development of versatile platforms of innovative vectors for cancer therapeutics, vaccine development and imaging reagents in nanomedicine

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Paul Laibinis
Professor of Chemical and Biomolecular Engineering

Research interests:
Self-assembly, surface engineering, interfaces, chemical sensor design, biosurfaces, nanotechnology

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Charles Lukehart
Professor of Chemistry

Research interests:
Discover and develop new synthesis strategies for the preparation of inorganic materials that exhibit desired chemical reactivity or interesting physical properties

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Website: vanderbilt.edu/chemistry/faculty/lukehart.php

Janet Macdonald
Assistant Professor of Chemistry

Research interests:
Nanomaterials chemistry, materials chemistry, inorganic chemistry

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Website: vanderbilt.edu/chemistry/faculty/macdonald.php

Florence Sanchez
Associate Professor of Civil and Environmental Engineering

Research interests:
Mass transfer in porous media coupled with chemical reactions for environmental systems and material aging

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Website: engineering.vanderbilt.edu/CivilAndEnvironmentalEngineering/People/FacultyDirectory/Sanchez_FacultyProfile.aspx

James Wittig
Associate Professor of Materials Science and Engineering; Director, VINSE Electron Microscopy Facility

Research interests:
Undercooled rapid quench processing, magnetic materials, analytical electron microscopy

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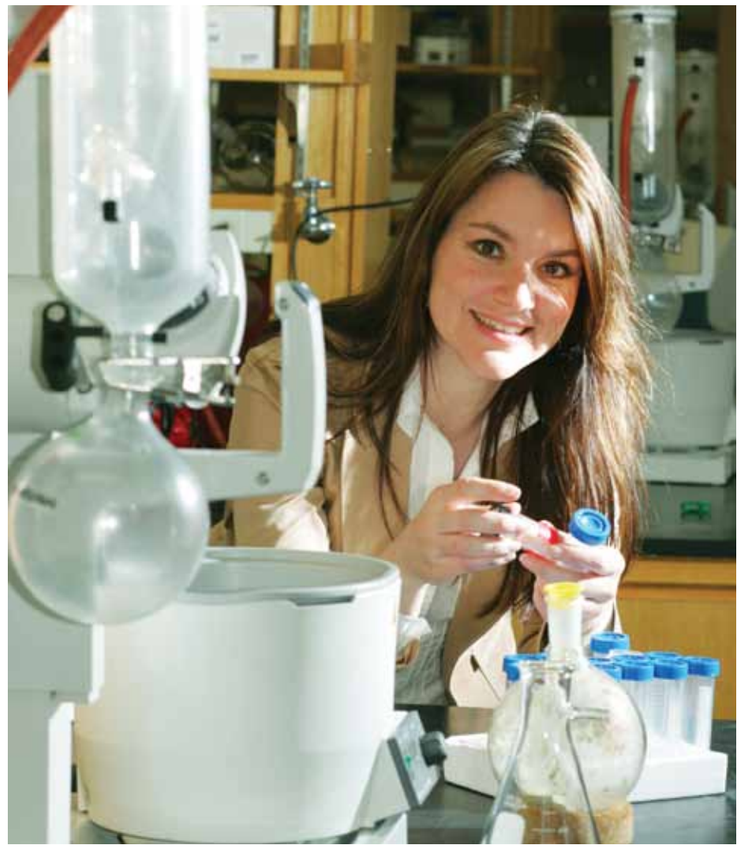
Website: frontweb.vuse.vanderbilt.edu/vuse_web/directory/facultybio.asp?FacultyID=23839



admissions

Graduate

To apply for admission to the Interdisciplinary Materials Science program at Vanderbilt, you must first meet the general requirements for admission by the Vanderbilt University Graduate School. Application for admission may be made electronically through the Graduate School website at *vanderbilt.edu/gradschool*.

The Graduate School Catalog may be viewed at *vanderbilt.edu/catalogs*.

Contact

Engineering Graduate Programs
ATTN: Interdisciplinary Materials Science
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DATES TO REMEMBER

October 22
Last date for applicants to take the paper-based general GRE

November 19
Last date for international applicants to take the Test of English as a Foreign Language (TOEFL)

December 1
Last date for applicants to take the computer-based (CBT), general GRE

January 15
Application deadline including all supporting credentials

February 15
Admission offers made

April 15
Deadline for applicants to respond to offers of admission

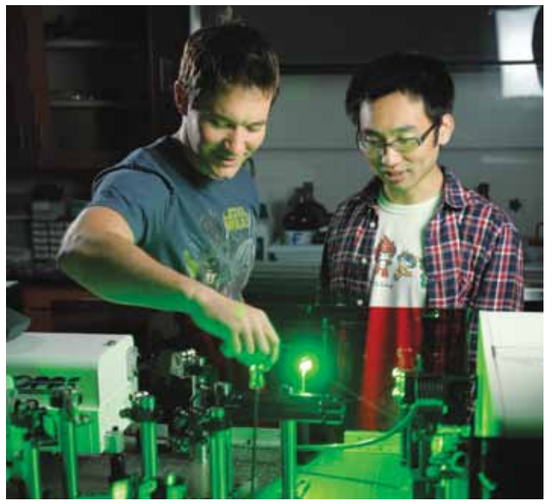
financial aid

Graduate

Students wishing to be considered for financial awards administered by the Graduate School should check the appropriate box under "Financial Information" on page 2 of the online application and make certain that a complete application is received by January 15. Prospective applicants are urged to apply for fellowships or grants from national, international, industrial, or foundation sources. More information can be found at *vanderbilt.edu/gradschool*.

Graduate students in the Interdisciplinary Materials Science program seeking the Ph.D. degree receive a competitive stipend, tuition waiver, health insurance and reimbursement for some incidental fees. This financial aid can be in the form of a Teaching Assistantship or a Research Assistantship.

- **Graduate Teaching Assistantships**
  Financial aid for the academic year to students who assist in supervised teaching of undergraduates
- **Graduate Research Assistantships**
  Financial aid for the calendar year to students carrying out thesis or dissertation research with support from a research grant



Teaching or Research Assistantships may be supplemented by a scholarship or fellowship through a competitive process supported by exceptional applicant qualifications. In order to be considered for these service-free awards, an applicant's file must be complete by January 15. The honor fellowships listed below are in addition to a Teaching or Research Assistantship.

- **Harold Stirling Vanderbilt (HSV) Graduate Scholarships**
  $6,000/year for up to five years
- **University Graduate Fellowships (UGF)**
  $10,000/year for up to five years
- **Provost's Graduate Fellowships (PGF)**
  $10,000/year for up to five years
- **School of Engineering Fellowships (IBM)**
  $4,000/year for up to four years plus an award of $1,000 for professional development

Prospective applicants are urged to apply for fellowships or grants from national, international, industrial, or foundation sources.

program setting

Vanderbilt

Cornelius Vanderbilt had a vision of a place that would "contribute to strengthening the ties that should exist between all sections of our common country" when he gave a million dollars to create a university in 1873. Today, that vision has been realized in Vanderbilt, an internationally recognized research university in Nashville, Tenn., with strong partnerships among its 10 schools, neighboring institutions, and the community.

Vanderbilt offers undergraduate programs in the liberal arts and sciences, engineering, music, education and human development, as well as a full range of graduate and professional degrees. The combination of cutting-edge research, liberal arts education, nationally recognized schools of law, business, engineering, and divinity, the nation's top-ranked graduate school of education, and a distinguished medical center creates an invigorating atmosphere where students tailor their education to meet their goals and researchers collaborate to address the complex questions affecting our health, culture, and society.

An independent, privately supported university, Vanderbilt is the largest private employer in Middle Tennessee and the second largest private employer based in the state.

Nashville

Vanderbilt's hometown of Nashville is a vibrant, engaging city known proudly as "Music City, U.S.A." The university's students, faculty, staff, and visitors frequently cite Nashville as one of the perks of Vanderbilt, with its 330-acre campus located a little more than a mile from downtown.

From serving as home to the nation's largest Kurdish population to being named America's friendliest city for three years in a row, Nashville is a metropolitan place that exudes all of the charm and hospitality one expects from a Southern capital.

The city was settled in 1779 and permanently became state capital in 1843. The city proper is 533 square miles with a population of nearly 570,000. Major industries include tourism, printing and publishing, technology manufacturing, music production, higher education, finance, insurance, automobile production, and health care management. Nashville has been named one of the 15 best U.S. cities for work and family by *Fortune* magazine, was ranked as the No. 1 most popular U.S. city for corporate relocations by *Expansion Management* magazine, and was named by *Forbes* magazine as one of the 25 cities most likely to have the country's highest job growth over the coming five years.

INSIGHT ○ INNOVATION ○ IMPACT®

The Vanderbilt University School of Engineering is internationally recognized for the quality of its research and scholarship. Engineering faculty and students share their expertise across multiple disciplines to address four specific research initiatives that characterize the School's commitment to help solve real-world challenges with worldwide impact. They are health care, energy and the environment, information systems, and defense and national security.
All programs leading to the bachelor of engineering degree are accredited by ABET, Inc., 11 Market Pl., Suite 1050, Baltimore, MD 21202, (410) 347-7700.

VANDERBILT UNIVERSITY

Interdisciplinary Materials Science
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ims.vanderbilt.edu

SCHOOL OF ENGINEERING