Materials Science & Engineering

The Institute of Materials Science & Engineering (IMSE) at Washington University in St. Louis offers a unique, interdisciplinary PhD in Materials Science & Engineering that crosses traditional departmental and school boundaries. The field of materials science and engineering focuses on the study, development and application of new materials with desirable properties, with the goal of enabling new products and superior performance regimes. Disciplines in the physical sciences (e.g., chemistry, physics) play a central role in developing the fundamental knowledge that is needed to design materials for a variety of engineering applications (e.g., mechanical engineering, electrical engineering, biomedical engineering). Building on training that spans from fundamental to applied sciences, materials scientists and engineers integrate this fundamental knowledge to develop new materials and match them with appropriate technological needs.

The IMSE is well positioned to address the needs of a student seeking a truly interdisciplinary experience. The IMSE brings together a diverse group of faculty from departments in Arts & Sciences, the McKelvey School of Engineering, and the School of Medicine. The IMSE also oversees shared research and instrument facilities, develops partnerships with industry and national laboratories, and facilitates outreach activities.

Current focused areas of research and advanced graduate education within the IMSE include the following:

- Artificial intelligence in materials discovery and design
- Biomedical, bio-derived, and bio-inspired materials
- Materials for energy and environmental technologies
- Quantum and photonic materials and devices

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Faculty

Director

Katharine M. Flores (https://engineering.wustl.edu/faculty/Katharine-Flores.html)
Christopher I. Byrnes Professor, Mechanical Engineering & Materials Science
PhD, Stanford University

Professor Flores' primary research interest is the mechanical behavior of high-performance structural materials, with particular emphasis on understanding structure-processing-property relationships in bulk metallic glasses and their composites.

Professors

Jianjun Guan (https://engineering.wustl.edu/faculty/Jianjun-Guan.html)
Professor, Mechanical Engineering & Materials Science
PhD, Zhejiang University

Professor Guan's research interests are in biomimetic biomaterials synthesis and scaffold fabrication; bioinspired modification of biomaterials; injectable and highly flexible hydrogels; bioimageable polymers for MRI and EPR imaging and oxygen sensing; mathematical modeling of scaffold structural and mechanical properties; stem cell differentiation; neural stem cell transplantation for brain tissue regeneration; and bone and cardiovascular tissue engineering.

Kenneth F. Kelton (https://physics.wustl.edu/people/kenneth-f-kelton/)
Arthur Holly Compton Professor of Arts & Sciences, Physics
PhD, Harvard University

Professor Kelton is involved in the study and production of titanium-based quasicrystals and related phases; fundamental investigations of time-dependent nucleation processes; modeling of oxygen precipitation in single crystal silicon; structure of amorphous materials; relation between structure and nucleation barrier; and hydrogen storage in quasicrystals.

Vijay Ramani (https://engineering.wustl.edu/Profiles/Pages/Vijay-Ramani.aspx)
Roma B. & Raymond H. Wittcoff Distinguished University Professor of Environment & Energy
PhD, University of Connecticut

Vijay Ramani's research interests lie at the confluence of electrochemical engineering, materials science and renewable and sustainable energy technologies. The National Science Foundation, Office of Naval Research, ARPA-E, and Department of Energy have funded his research, with mechanisms including an NSF CAREER award (2009) and an ONR Young Investigator Award (ONR-YIP; 2010).

Srikanth Singamaneni (https://engineering.wustl.edu/Profiles/Pages/Srikanth-Singamaneni.aspx)
The Lilyan & E. Lisle Hughes Professor, Mechanical Engineering & Materials Science
PhD, Georgia Institute of Technology

Professor Singamaneni's research interests include plasmonic engineering in nanomedicine (in vitro biosensing for point-of-care diagnostics, molecular bioimaging, nanotherapeutics); photovoltaics (plasmonically enhanced photovoltaic devices); surface-enhanced Raman scattering (SERS)-based chemical sensors, with particular emphasis on the design and fabrication of unconventional and highly efficient SERS substrates; hierarchical organic/inorganic nanohybrids as multifunctional materials; bioinspired structural and functional materials; polymer surfaces and interfaces; responsive and adaptive materials and scanning probe microscopy; and surface force spectroscopy of soft and biological materials.

Fuzhong Zhang (https://engineering.wustl.edu/faculty/Fuzhong-Zhang.html)
Professor, Energy, Environmental & Chemical Engineering
PhD, University of Toronto

Professor Zhang's research focuses on developing synthetic biology tools and systems for the sustainable production of structurally defined chemicals and high-performance materials. Current research projects include the following: (1) engineering microbial metabolic dynamics and heterogeneity; (2) engineering metabolic pathways to produce structure-defined biofuels and chemicals; and (3) developing microbial factories to produce high-performance materials.

Associate Professors

Peng Bai (https://engineering.wustl.edu/faculty/Peng-Bai.html)
Associate Professor, Energy, Environmental & Chemical Engineering
PhD, Tsinghua University, Beijing

Professor Bai's research focuses on the development of next-generation batteries. Knowledge and tools developed in the Bai Group also apply to and benefit the design of other electrochemical energy systems, like supercapacitors and fuel cells.

Mikhail Y. Berezin (https://profiles.wustl.edu/en/persons/mikhail-berezin/)
Associate Professor, Radiology
PhD, Moscow Institute of Oil and Gas/Institute of Organic Chemistry

Dr. Berezin's lab focuses on the development of novel optically active probes ranging from small molecules to nanoparticles and the development of optical instrumentation for spectroscopy and imaging using knowledge of excited states. The lab's research interest lies in the investigation and application of molecular excited states and their reactions for medical imaging and clinical treatment.

Marcus Foston (https://engineering.wustl.edu/faculty/Marcus-Foston.html)
Associate Professor, Energy, Environmental & Chemical Engineering
PhD, Georgia Institute of Technology

Professor Foston's research program seeks to develop innovative and novel routes to exploit and utilize lignocellulosic biomass by taking advantage of materials involved in industries such as agriculture, papermaking, and forestry products.

Erik Henriksen (https://physics.wustl.edu/people/erik-henriksen/)
Associate Professor, Physics
PhD, Columbia University

Professor Henriksen's lab research is centered on the properties of electrons confined to two dimensions. This remarkable system has yielded a tremendous amount of interesting and important physics over the past several decades, from the integer and fractional quantum Hall effects to the groundbreaking discoveries of graphene and other atomically thin crystals and especially to the recent realization of the topological nature of the electronic structure of a surprising number of materials both novel and familiar.

Song Hu (https://engineering.wustl.edu/faculty/Song-Hu.html)
Associate Professor, Biomedical Engineering
PhD, Washington University in St. Louis

Professor Hu's research focuses on the development of cutting-edge optical and photoacoustic technologies for high-resolution structural, functional, metabolic and molecular imaging in vivo and their applications in neurovascular disorders, cardiovascular diseases, regenerative medicine, and cancer.

Matthew Lew (https://engineering.wustl.edu/faculty/Matthew-Lew.html)
Associate Professor, Electrical & Systems Engineering
PhD, Stanford University

Professor Lew and his students build advanced imaging systems to study biological and chemical systems at the nanoscale, leveraging innovations in applied optics, signal and image processing, design optimization, and physical chemistry. Their advanced nanoscopes (microscopes with nanometer resolution) visualize the activity of individual molecular machines inside and outside living cells. Examples of new technologies developed in the Lew Lab include (1) using tiny fluorescent molecules as sensors that can detect amyloid proteins; (2) designing new "lenses" to create imaging systems that can visualize how molecules move and tumble; and (3) new imaging software that minimizes artifacts in super-resolution images.

Xianglin Li (https://engineering.wustl.edu/faculty/Xianglin-Li.html)
Associate Professor, Mechanical Engineering & Materials Science
PhD, University of Connecticut

Professor Li's research interests are in batteries and fuel cells, including direct methanol fuel cells, lithium-oxygen batteries and battery thermal management; transport phenomena in porous media; greenhouse gas emissions and full fuel cycle analysis of fossil fuels; and life cycle assessment and economic analysis of advanced energy techniques, among others.

Mark Meacham (https://engineering.wustl.edu/faculty/Mark-Meacham.html)
Associate Professor, Mechanical Engineering & Materials Science
PhD, Georgia Institute of Technology

Professor Meacham's research interests include microfluidics, micro-electromechanical systems (MEMS) and associated transport phenomena, with application to design, development and testing of novel energy systems and life sciences tools, from scalable micro-/nanotechnologies for improved heat and mass exchangers to MEMS-based tools for manipulation and investigation of cellular processes. He is also interested in the behavior of jets and/or droplets of complex fluids during ejection from microscopic orifices, which is critical to applications as disparate as biological sample preparation and additive manufacturing.

Rohan Mishra (https://engineering.wustl.edu/faculty/Rohan-Mishra.html)
Associate Professor, Mechanical Engineering & Materials Science
PhD, Ohio State University

Professor Mishra's research interest is to develop quantitative structure-property correlations in materials starting from the atomic scale. To develop such correlations, his group synergistically combines electronic structure calculations with atomic-resolution electron microscope imaging and spectroscopy. The end goal is the rational design of materials with properties tailored for electronic, optical, magnetic and energy applications. Current research topics include perovskite materials for photovoltaic and optoelectronic applications, novel electrocatalysts, oxidizers, and wide-bandgap semiconductors.

Michelle Oyen (https://engineering.wustl.edu/faculty/Michelle-Oyen.html)
Associate Professor, Biomedical Engineering
PhD, University of Minnesota

Professor Oyen has a background in materials and biomechanics and has worked on many problems within tissue mechanics and biomimetic materials. For over twenty years, she has had an increasing interest in pregnancy and women's health research, particularly in engineering approaches for prevention of and intervention into preterm birth.

Jai Rudra (https://engineering.wustl.edu/faculty/Jai-Rudra.html)

Associate Professor, Biomedical Engineering
PhD, Louisiana Tech University

Jai Rudra's lab is interested in the development of nanoscale biomaterials such as nanofibers, nanoparticles, virus-like particles, and hydrogels for engaging the immune system to induce protective antibody and cell-mediated immune responses against diseases such as tuberculosis, melanoma, and flavivirus infections (i.e., West Nile and Zika). He is also investigating the development of vaccines against drugs of addiction such as cocaine.

Elijah Thimsen (https://engineering.wustl.edu/faculty/Elijah-Thimsen.html)
Associate Professor, Energy, Environmental & Chemical Engineering
PhD, Washington University in St. Louis

Professor Thimsen's research focus is on the synthesis of nanostructured materials and molecular chemicals using non-equilibrium plasma and aerosol approaches.

Chuan Wang (https://engineering.wustl.edu/faculty/Chuan-Wang.html)
Associate Professor, Electrical & Systems Engineering
PhD, University of Southern California

Professor Wang's research focus is on two-dimensional semiconductor nanoelectronics and optoelectronics, stretchable electronics, printed electronics, and sensors and actuators.

Assistant Professors

Sang-Hoon Bae (https://engineering.wustl.edu/faculty/Sang-Hoon-Bae.html)
Assistant Professor, Mechanical Engineering & Materials Science
PhD, University of California, Los Angeles

Professor Bae's research group focuses on tackling the challenges in materials science with thermodynamics, kinetics, and solid-state physics.

Nathaniel Huebsch (https://engineering.wustl.edu/faculty/Nathaniel-Huebsch.html)
Assistant Professor, Biomedical Engineering
PhD, Harvard University

Professor Huebsch's research focus is in basic and translational stem cell mechanobiology, with specific focus on hydrogels to control cell-mediated tissue repair and three-dimensional, iPSC-based heart-in-a-dish models to study the influence of mechanical loading and genetics on arrhythmia and contractility.

Mark Lawrence (https://engineering.wustl.edu/faculty/Mark-Lawrence.html)
Assistant Professor, Electrical & Systems Engineering
PhD University of Birmingham

Professor Lawrence and his lab are harnessing breakthroughs in nanoscale engineering to push the limits of light-based technologies, targeting applications ranging from all-optical computing and quantum communication to metrology and biosensing.

Sheng Ran (https://physics.wustl.edu/people/sheng-ran/)
Assistant Professor, Physics
PhD, Iowa State University

Professor Ran's research aims to realize and understand exotic states of quantum materials using combined techniques of bulk crystal synthesis, electric and thermal transport measurements under extreme temperature, pressure and magnetic field conditions, and neutron and high-energy X-ray scattering.

Patricia Weisensee (https://engineering.wustl.edu/faculty/Patricia-Weisensee.html)
Assistant Professor, Mechanical Engineering & Materials Science
PhD, University of Illinois at Urbana-Champaign

Professor Weisensee's work focuses on understanding the interplay of fluid dynamics, heat transfer, and liquid-solid interactions of droplets and other multi-phase systems. Practical applications of interest are phase change heat transfer for thermal management, thermal storage, water harvesting, metallic additive manufacturing, and droplet interactions with biological and natural systems.

Chong Zu (https://physics.wustl.edu/people/chong-zu/)
Assistant Professor, Physics
PhD, Tsinghua University

Professor Zu's research interests lie at the interface between atomic, molecular, and optical physics; condensed matter physics; and quantum information.

Degree Requirements

Interdisciplinary PhD in Materials Science & Engineering

To earn a PhD degree, students must complete the requirements of the McKelvey School of Engineering, along with program-specific requirements. Courses include the following:

- Four IMSE Core Courses (12 units)

Code	Title	Units
MEMS 5610	Quantitative Materials Science & Engineering	3
MEMS 5619	Thermodynamics of Materials	3
or EECE 502	Advanced Thermodynamics in EECE	
Physics 537	Kinetics of Materials	3
Chem 5620	Solid-State and Materials Chemistry (or Physics 5072 Solid State Physics)	3
Total Units		**12**

- Two semesters of IMSE 500 First-Year Research Rotation (6 units)
- Three courses (9 units) from a preapproved list of Materials Science & Engineering electives
- A minimum of three graduate-level technical elective courses (9 units) in mathematics or any science or engineering department, to reach a total of at least 36 academic credit units
  - A maximum of 3 units of IMSE 505 Material Science Journal Club will be permitted toward this requirement.
  - Any 400-level courses not included on the preapproved list of Materials Science & Engineering electives must be approved by the Graduate Studies Committee.
- A maximum of 12 units of 400-level courses may be applied toward the required 36 academic credit units. Undergraduate-only courses (below the 400 level) are generally not permitted and may not be used to fulfill this requirement.
- IMSE 501 IMSE Graduate Seminar every semester of full-time enrollment
- 18 to 36 units of IMSE 600 Doctoral Research (Students must identify an IMSE faculty member willing and able to support their dissertation research on a materials-related topic.)
- Students must maintain a grade-point average of at least 3.0 for all graded courses and have no more than one grade of B- or below in a core course or a Materials Science & Engineering elective.

Additional program requirements include the following:

- Pass the IMSE Qualifying Examination (oral and written components)
- Identify an IMSE graduate program faculty member willing and able to support the student's dissertation research on a materials-related topic
- Maintain satisfactory research progress on a topic in materials science and engineering, as determined by the dissertation advisor and the mentoring committee
- Successfully complete research ethics training by the end of the third semester
- Successfully complete teaching requirements by the end of the third year:
  - Attend two or more Teaching Center workshops
  - Complete 15 units of Mentored Teaching Experience
- Successfully complete the dissertation proposal and presentation, with approval from the dissertation examination committee
- Successfully complete and defend a PhD dissertation, with final approval from the dissertation examination committee

Failure to meet these requirements will result in dismissal from the program.

Recommended Course Plan

Year 1

Fall Semester (12 credits)

- IMSE First-Year Research Rotation (IMSE 500)
- IMSE Graduate Seminar (IMSE 501)
- Quantitative Materials Science & Engineering (MEMS 5610)
- Thermodynamics of Materials (MEMS 5619) (or elective if taking Advanced Thermodynamics in EECE (EECE 502) in the spring)
- Solid-State and Materials Chemistry (Chem 5620) (or elective if taking Solid State Physics (Physics 5072) in the spring)

Spring Semester (12 credits)

- IMSE First-Year Research Rotation (IMSE 500)
- IMSE Graduate Seminar (IMSE 501)
- Kinetics of Materials (Physics 537)
- Solid State Physics (Physics 5072) (if Chem 5620 not taken in the fall) or elective
- Advanced Thermodynamics in EECE (EECE 502) (if MEMS 5619 not taken in the fall) or elective

Summer

- Begin dissertation research
- Prepare for IMSE Qualifying Examination (typically taken in August):
  - Written document and oral presentation on research rotation
  - Oral examination on fundamentals from core courses
- Participate in Graduate Student Mentored Teaching Orientation offered in August by the Center for Teaching and Learning (if not completed during the fall orientation)

Years 2 and Beyond

- Complete remaining electives (discuss with dissertation advisor)
- IMSE Graduate Seminar (IMSE 501)
- Doctoral Research (IMSE 600)
- Teaching requirements (to be completed by the end of the third year):
  - Attend two or more Teaching Center workshops
  - Complete 15 units of Mentored Teaching Experience
- Regular meetings (at least once per year) with the mentoring committee
- Dissertation proposal and presentation (fifth semester)
- Dissertation and oral defense