Materials Science & Engineering

The Institute of Materials Science and Engineering (IMSE) at Washington University in St. Louis offers a truly interdisciplinary PhD in Materials Science & Engineering. Materials Science & Engineering is the interdisciplinary field focused on the development and application of new materials with desirable properties and microstructures. Disciplines in the physical sciences (chemistry, physics, etc.) and engineering fields (mechanical engineering, electrical engineering, biomedical engineering, etc.) frequently play a central role in developing the fundamental knowledge that is needed for materials studies. The discipline of Materials Science & Engineering integrates this knowledge and uses it to design and develop new materials and to match these with appropriate technological needs.

The IMSE is well positioned to address the needs of a student seeking a truly interdisciplinary experience. Established in 2013, the IMSE brings together more than 30 research groups in Arts & Sciences, the School of Engineering & Applied Science, and the Medical School. The IMSE works to integrate and expand the existing materials interests at Washington University by establishing and overseeing shared research and instrument facilities, creating partnerships with industry and national facilities, and setting up outreach activities.

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

Plasmonics, Photonics, and Materials for Sensors and Imaging (http://imse.wustl.edu)
Computational Materials Science (http://imse.wustl.edu/research-computational)
Energy Harvesting and Storage (http://imse.wustl.edu/research-energy)
Structure, Properties, and Phase Transformations of Complex Materials (http://imse.wustl.edu/research-glasses)
Environmental Technologies and Sustainability (http://imse.wustl.edu/research/environmental-technologies-and-sustainability)

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Email: bgartin@wustl.edu
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Faculty

**Director**
Kenneth F. Kelton (http://www.physics.wustl.edu/people/kelton_kenneth-f)
Arthur Holly Compton Professor of Arts & Sciences - Physics
PhD, Harvard University

**Associate Director**
Katharine M. Flores (https://engineering.wustl.edu/Profiles/Pages/Kathy-Flores.aspx)
Professor - Mechanical Engineering & Materials Science
PhD, Stanford University
Professor Flores' primary research interest is the mechanical behavior of structural materials, with particular emphasis on understanding structure-processing-property relationships in bulk metallic glasses and their composites.

**Professors**
Sophia E. Hayes (http://www.chemistry.wustl.edu/people/primary-faculty/sophia-e-hayes)
Professor - Chemistry
PhD, University of California, Santa Barbara
Physical inorganic chemistry; materials chemistry; solid-state NMR; magnetic resonance; optically-pumped NMR (OPNMR); semiconductors; quantum wells; magneto-optical spectroscopy; quadrupolar NMR of thin films and tridecameric metal hydroxide clusters and thin films; carbon capture, utilization and storage (CCUS); CO2 geosequestration; CO2 capture; in situ NMR; metal carbonate formation.

Lan Yang (https://engineering.wustl.edu/Profiles/Pages/Lan-Yang.aspx)
Edwin H. & Florence G. Skinner Professor - Electrical & Systems Engineering
PhD, California Institute of Technology
Professor Yang’s research interests are fabrication, characterization, and fundamental understanding of advanced nano/micro photonic devices with outstanding optical properties. Currently, her group focuses on the silicon-chip based ultra-high-quality micro-resonators made from spin-on glass. The spin-on glass is a kind of glass obtained by curing a special liquid using sol gel or wet chemical synthesis to form a layer of glass. The main advantage of the spin-on glass is the easy tailoring of the nano/micro structure of the glass by controlled variation in the precursor solutions. It enables them to fabricate various micro/nano photonic devices from advanced materials with desired properties.
**Associate Professors**

**Young-Shin Jun** ([https://engineering.wustl.edu/Profiles/Pages/Young-Shin-Jun.aspx](https://engineering.wustl.edu/Profiles/Pages/Young-Shin-Jun.aspx))
Harold D. Jolley Career Development Associate Professor - Energy, Environmental & Chemical Engineering
PhD, Harvard University
Professor Jun's research is highly interdisciplinary as the Jun group seeks to enable more environmentally sustainable CO2 sequestration as a mitigation technique for climate change. The group also develops nanochemistry-enabled new treatment techniques and catalysts for purifying drinking water and remediating contaminated water and soil, benefiting water reuse, managed aquifer recharge, and reverse osmosis processes. In addition, the ENCL investigates biominalization and bio-inspired chemistry for novel materials development.

**Srikanth Singamaneni** ([https://engineering.wustl.edu/Profiles/Pages/Srikanth-Singamaneni.aspx](https://engineering.wustl.edu/Profiles/Pages/Srikanth-Singamaneni.aspx))
Associate 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.

**Assistant Professors**

**Parag Banerjee** ([https://engineering.wustl.edu/Profiles/Pages/Parag-Banerjee.aspx](https://engineering.wustl.edu/Profiles/Pages/Parag-Banerjee.aspx))
Assistant Professor - Mechanical Engineering & Materials Science
PhD, University of Maryland, College Park
Professor Banerjee's research interests focus on two aspects of materials science and engineering. First, he is interested in the synthesis of nanomaterials with tunable properties using principles of self-assembly and self-limited reactions. Second and perhaps more importantly, he is interested in integrating these materials into "performance enhancing" nano-architectures for components such as biomedical sensors, energy storage, and energy harvesting devices.

**Mikhail Y. Berezin** ([http://dbbs.wustl.edu/faculty/Pages/faculty_bio.aspx?SID=6263](http://dbbs.wustl.edu/faculty/Pages/faculty_bio.aspx?SID=6263))
Assistant Professor - Radiology
PhD, Moscow Institute of Oil and Gas / Institute of Organic Chemistry
Professor Berezin's research interest lies in the investigation and application of molecular excited states and their reactions for medical imaging and clinical treatment. Excited states are the cornerstone of a variety of chemical, physical, and biological phenomena. The ability to probe, investigate, and control excited states is one of the largest achievements of modern science. The 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 and their applications in medicine.

**Julio D'Arcy** ([http://www.chemistry.wustl.edu/faculty/darcy](http://www.chemistry.wustl.edu/faculty/darcy))
Assistant Professor - Chemistry
PhD, University of California, Los Angeles
The overarching goals of the D'Arcy laboratory are to discover and apply novel functional nanostructured organic and inorganic materials utilizing universal synthetic chemistry protocols that control chemical structure, nanoscale morphology, and intrinsic properties. We are interested in capacitive and pseudocapacitive nanostructured materials such as conducting polymers, metal oxides, and carbon allotropes possessing enhanced chemical and physical properties, i.e., charge carrier transport, ion transport, surface area, thermal and mechanical stability. Our concerted material discovery process is a multi-pronged approach: organic and inorganic nanostructured materials are synthesized via solution processing, electrochemistry, vapor phase deposition, and combinations thereof. Alternatively, we also develop self-assembly techniques that result in tailored materials.

**Erik Henriksen** ([https://www.physics.wustl.edu/people/henriksen_erik](https://www.physics.wustl.edu/people/henriksen_erik))
Assistant Professor - Physics
PhD, Columbia University
We are an experimental condensed matter research lab with interests primarily in the quantum electronic properties of graphene and other novel two-dimensional systems. We utilize state-of-the-art nanofabrication techniques in combination with measurements made at low temperatures and high magnetic fields to explore both the fundamental electronic structures and emergent quantum phenomena of low-dimensional materials.
Cynthia Lo  
Assistant Professor - Energy, Environmental & Chemical Engineering  
PhD, Massachusetts Institute of Technology  
Professor Lo uses electronic structure calculations and molecular dynamics simulations to study the structure and reactivity of molecular and nanoscale systems for solar energy utilization. Some applications of current interest include bio-hybrid solar cells, photosynthesis, transparent conducting oxides for photovoltaic and thermoelectric applications, and multifunctional heterogeneous catalysts and photocatalysts. In addition, Professor Lo is interested in developing multiscale computational methods that link existing methods across time and length scales in order to model complex chemical systems.

Rohan Mishra (https://engineering.wustl.edu/Profiles/Pages/Rohan-Mishra.aspx)  
Assistant Professor - Mechanical Engineering & Materials Science  
PhD, The Ohio State University  
In his lab at Washington University, Mishra plans to identify and develop a quantitative measure of structure-property correlations in materials, such as epitaxial thin films and materials with reduced dimensionality, using a synergistic combination of scanning transmission electron microscopy and atomic-scale theory, to create rational design of materials with properties tailored for electronic, magnetic, optical and energy applications.

Bryce Sadtler (http://www.chemistry.wustl.edu/faculty/sadtler)  
Assistant Professor - Chemistry  
PhD, University of California, Berkeley  
The Sadtler research group seeks to understand and control structure-property relationships in adaptive, mesostructured materials. Through hierarchical design of the atomic composition, nanoscale morphology, and mesoscale organization of the individual components, we can direct the emergent chemical reactivity and physical properties of these complex systems. Research projects combine solution phase growth techniques to synthesize inorganic materials, external fields to control the growth and assembly of mesoscale architectures, and super-resolution imaging to provide spatiotemporal maps of the optical response and photocatalytic activity during the morphological evolution of these structures. Knowledge gained from these fundamental studies will be used to create functional materials, including plasmonic substrates that enhance absorption in thin-film semiconductors, mesostructured photocatalysts for solar fuels generation, and chemical sensors based on self-assembled photonic structures.

Simon Tang (http://www.orthoresearch.wustl.edu/content/Laboratories/3043/Simon-Tang/Tang-Lab/Overview.aspx)  
Assistant Professor - Orthopaedics  
PhD, Rensselaer Polytechnic Institute  
With the overall theme of understanding the biological regulation of skeletal matrix quality, our research group integrates engineering and biology approaches for (1) understanding the effect of disease mechanisms on the structure-function relationships of skeletal tissues and (2) developing of translatable therapeutic and regenerative strategies for these diseases. The investigation of these scientific questions includes the application of finite element analyses, multiscale tissue mechanics, and the functional imaging of skeletal tissues for regenerative medicine with in vitro and in vivo biological systems.

Elijah Thimsen (https://engineering.wustl.edu/Profiles/Pages/Elijah-Thimsen.aspx)  
Assistant Professor - Energy, Environmental & Chemical Engineering  
PhD, Washington University  
The Interface Research Group focuses on advanced gas-phase synthesis of nanomaterials for energy applications. We are currently exploring nonthermal plasma synthesis and atomic layer deposition (ALD). The goal is to discover and then understand useful interfacial phenomena. Examples of applications we are currently interested in are: transparent conducting oxides, photovoltaics, lithium-sulfur batteries, and coatings for high-temperature combustion.

Fuzhong Zhang (https://engineering.wustl.edu/Profiles/Pages/Fuzhong-Zhang.aspx)  
Assistant Professor - Energy, Environmental & Chemical Engineering  
PhD, University of Toronto  
Professor Zhang’s research interests focus on developing synthetic biology approaches to produce advanced biofuels, chemicals, and materials from sustainable resources. Current research projects include: (1) developing dynamic regulatory systems for biosynthetic pathways; (2) engineering microbes to produce structure-defined biofuels and chemicals; (3) developing microbial factories for advanced materials; (4) engineering cyanobacteria for synthetic biology applications.

**Degree Requirements**

**Interdisciplinary PhD in Materials Science & Engineering**

To earn a PhD degree, students must complete the Graduate School requirements, along with specific program requirements. Course work includes:

- Four IMSE Core Courses (12 academic credits)

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<tr>
<th>Code</th>
<th>Title</th>
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<tr>
<td>MEMS 5601</td>
<td>Mechanical Behavior of Materials</td>
<td>3</td>
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3
MEMS 5608  Introduction to Polymer Science and Engineering  3
MEMS 5610  Quantitative Materials Science and Engineering  3
Physics 537  Thermodynamics & Kinetics of Materials  3

Total units  12

- Solid State Chemistry or Physics (3 academic credits)

Code  Title  units
Chem 465  Solid-State and Materials Chemistry  3
or Physics 472  Solid State Physics

- IMSE 500 First-Year Research Rotation (3 academic credits)
- IMSE 501 Seminar (1 academic credit; 2 required, 3 allowed for credit)
- Three courses (9 credits) from a preapproved list of Materials Science & Engineering electives
- Additional electives from participating departments to reach 36 academic credits (~9 academic credits, ~3 courses)
- A maximum of 12 credits of 400-level courses may be applied to the required 36 academic credits

Students must maintain an average grade of B (GPA 3.0) for all 72 credits. Additionally, the required courses must be completed with no more than one grade below a B-. Up to 24 graduate credits may be transferred with the approval of the Graduate Studies Committee, chaired by the Associate Director of the IMSE.

In addition to fulfilling the course and research credit requirements, the student must:

- Complete a Research Rotation
- Identify an IMSE faculty member willing and able to support the student's thesis research on a materials-related topic
- Fulfill the Teaching Requirement
  - Attend 2+ Teaching Center Workshops
  - 15 units of teaching experience (basic and advanced levels)
- Successfully complete the Qualifying Examination (oral and written)
- Maintain satisfactory research progress, as determined by the student's thesis adviser and mentoring committee
- Successfully complete the Thesis Proposal and Presentation
- Successfully complete and defend a dissertation

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

Course Plan

Year 1

Fall Semester (13 credits)
- Solid State and Materials Chemistry (Chem 465) or elective
- Quantitative Materials Science and Engineering (MEMS 5610)
- Mechanical Behavior of Materials (MEMS 5601)
- Elective
- IMSE Seminar

Spring Semester (13 credits)
- Thermodynamics & Kinetics of Materials (Physics 537)
- Introduction to Polymer Science and Engineering (MEMS 5608)
- Solid State Physics (Physics 472) or elective
- IMSE First-Year Research Rotation
- IMSE Seminar Series

Summer
- Begin thesis research
- Prepare for Qualifying Exam (August)
  - Written document and oral presentation on research rotation
  - Oral exam on fundamentals from core courses

Years 2 and beyond
- 3 electives (discuss with PhD adviser)
- IMSE Seminar (once more for credit)
- IMSE PhD Research
- Teaching Requirement
  - Attend 2+ Teaching Center Workshops
  - 15 units of teaching experience (basic and advanced levels)
- Annual (or more frequent) meetings with Faculty Mentoring Committee
- Thesis proposal and presentation (fifth semester)
- Dissertation and oral defense