



MIT
MATERIALS
RESEARCH
LABORATORY

MATERIALS RESEARCH AT THE NANOSCALE MATERIALS DAY

Materials Resources

The Materials Research Laboratory (MRL) serves interdisciplinary groups of faculty, staff and students, supported by industry, foundations and government agencies to carry out fundamental engineering research on materials. Research topics include energy conversion and storage; quantum materials; spintronics; photonics; metals; integrated microsystems; materials sustainability; solid-state ionics; complex oxide electronic properties; biogels; and functional fibers.
<https://mrl.mit.edu>

The MRL MRSEC (formerly MIT MRSEC) at MIT is one of a nation-wide network of Materials Research Science and Engineering Centers sponsored by the National Science Foundation (NSF).
<https://mitcmse.mit.edu>

The Crystal Physics and Electroceramics Laboratory is devoted to the modeling, processing, characterization and optimization of energy related devices (sensors, batteries, fuel cells, solar/photolysis cells) and the integration of sensor, actuator and photonic materials into microelectromechanical (MEMS) systems.
<http://electroceramics.scripts.mit.edu/>

Microphotonics Center @ MIT builds interdisciplinary teams, focused on collaborative research for the advancement of basic science and emerging technology pertaining to integrated photonic systems.
<https://mphotronics.mit.edu>

The Communications Technology Roadmap (CTR) is a project under the Microphotonics Center Industry Consortium, and is a part of the MIT Microphotonics Center. The purpose of this Roadmap is to understand the interaction between technology, industry, and policy dynamics and from there, formulate a vision for the future of the microphotonics industry.
<http://mph-roadmap.mit.edu/>

The AIM Photonics Academy launched in 2016 as the education, workforce development, and roadmapping arm of AIM Photonics, one of 14 public-private manufacturing innovation institutes created as part of a federal initiative to revitalize American manufacturing. Currently, the AIM Photonics Academy administrative offices are hosted at MIT. The AIM Photonics Academy's mission is to educate the current and future workforce in integrated photonics – technologies that will lead to the next generation of faster and more power-efficient chips.
<https://aimphotonics.academy/>

The Skoltech Center for Electrochemical Energy Storage (CEES) is an inter-university/interdepartmental center with three major goals; development of advanced lithium ion and multivalent ion batteries, the development of rechargeable metal-air batteries, and the development of reversible low and elevated temperature fuel cells.
<https://cees-www.mit.edu/>

Department of Materials Science & Engineering is known as the world-wide leader in its field, pioneering advances in engineering sciences and technologies.
<https://dmse.mit.edu>

MATERIALS DAY AT MIT

Materials Research at the Nanoscale

October 10, 2018

The theme of this year's symposium will largely be focused on imaging-enabled nanoscale research on the structure, properties and processing of materials. Invited speakers will describe new tools and methods for atomic-scale structural and chemical characterization of materials, and application of these methods to optimization of processing and properties of materials for a wide range of applications. Results from imaging-based in situ studies of vapor- and liquid-phase processes for synthesis of nanostructured materials and in situ studies of nano- and micro-scale phenomena that can be used to engineer properties of bulk materials will be presented. Development of compact high-brilliance X-ray sources that can provide synchrotron-level materials analyses with laboratory-scale systems will also be discussed. Studies of nanoscale electronic, photonic, mechanical and catalytic properties of materials will be included and discussion of prospects for development of new state-of-the-art tools and methods for imaging-based and x-ray based materials research will be featured.

The poster session immediately follows the symposium and showcases students research and it's applications. About sixty-five posters are presented each year, on a full range of research topics.

Materials Research Laboratory
Massachusetts Institute of Technology
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Cambridge, MA 02139
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email: mit-mrl@mit.edu

Materials Day Agenda

8:00am

Registration

8:45 - 9:00am

Welcome and Overview

Carl V. Thompson

Director, Materials Research Laboratory

Professor, Department of Materials Science & Engineering, MIT

Session I:

9:00 - 9:30am

Keynote:

Application of Advanced Microscopy to Industrial Problems: New Tools Give New Insights

Dr. Matthew Kulzick

Senior Research Chemist, BP Amoco Chemical Company

9:30 - 10:00am

Imaging and Controlling Nanoscale Crystal Growth in the Transmission Electron Microscope

Professor Frances M. Ross

Department of Materials Science & Engineering, MIT

10:00 - 10:30am

An Electron Walks Into a Bar... Electron Microscopy Beyond Imaging

Professor Sylvija Gradečak

Department of Materials Science & Engineering, MIT

10:30 - 11:00am

BREAK

Session II:

11:00 - 11:30am

Compact Synchrotron Radiation Sources Enabling Advanced X-ray Imaging and Diffraction Methods in a Laboratory Setting

Dr. David E. Moncton

Director, Nuclear Reactor Laboratory, MIT

11:30 - 12:00pm

Nanoscale Insights for Macroscale Solutions: Exploring Novel Damage-resistance Mechanisms in Metals

Professor Cem Tasan

Department of Materials Science & Engineering, MIT

Agenda cont'd

12:00 - 1:30pm

LUNCH

Stratton Student Center, 3rd Floor
Twenty Chimneys/Mezzanine Lounge (Building W20-306 & 307)

Session III:

1:30 - 2:00pm

Accelerating the Pace of Materials Characterization at the Atomic Scale: From Machine Learning to Novel Detectors

Dr. James LeBeau
Associate Director, Analytical Instrumentation Facility, NCSU

2:00 - 2:30pm

Using Quantum Mechanics to Hack the Electron Microscope

Professor Karl Berggren
Department of Electrical Engineering & Computer Science, MIT

2:30 - 3:30pm

Poster Preview: 2 minute talks by selected poster presenters

3:30 - 3:35pm

Session Wrap Up

Carl V. Thompson, Professor, Department of Materials Science & Engineering
Director, Materials Research Laboratory, MIT

3:35 - 5:30pm

Poster Session and Social

La Sala de Puerto Rico,
2nd Floor, Stratton Student Center (Building W20-202)

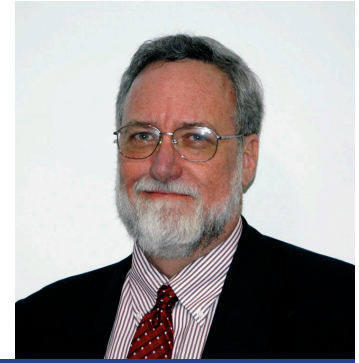
5:30pm

Poster Awards

5:45pm

Adjourn

Professor Carl V. Thompson
Director
Materials Research Laboratory
Stavros Salapatas Professor of Materials
Science and Engineering
Department of Materials Science and
Engineering, MIT



Welcome and Overview

Biography: Professor Thompson received an S.B. in Materials Science and Engineering from MIT and a Ph.D. in Applied Physics from Harvard University. He joined the MIT faculty in 1983. He is the Director of MIT's new Materials Research Laboratory and co-directs the Skoltech Center for Electrochemical Energy Storage. He previously directed the Materials Processing Center and co-chaired the Materials for Micro- and Nano-systems program of the Singapore-MIT Alliance for twelve years. He is also a past president and Fellow of the Materials Research Society. Professor Thompson's research interests include processing of thin films and nanostructures for applications in microelectronic, microelectromechanical and electrochemical systems. Current activities focus on development of thin film batteries for autonomous microsystems, the reliability of IC interconnects and GaN-based devices, and morphological stability of thin films and nano-scale structures.

Application of Advanced Microscopy to Industrial Problems: New Tools Give New Insights

Abstract: Dr. Kulzick will highlight a range of applications where advanced electron microscopy methods are being used by BP to develop deeper insight into challenging systems. These will include examples in catalysis, asphaltene agglomeration, separation science, and corrosion. These examples have been developed through BP's International Center for Advanced Materials or ICAM working with researchers at University of Manchester and University of Illinois at Champaign Urbana. The goal of the talk is to illustrate how recent advances in electron microscopy are allowing industrially relevant systems to be studied in detail at nanoscale and the criticality of industry-academic collaboration to advance this type of understanding.

Biography: Dr. Kulzick joined BP Amoco Chemical Company in 1984 after receiving his Ph.D. in Inorganic Chemistry from the University of California in Berkeley where he worked with Professor E. Meutterties on synthetic organometallic chemistry. He has a B.S. in chemistry from University of Wisconsin. In industry, he has worked in a wide range of areas including catalysis, polymer science, coating development, and active barrier packaging. In 2003, he was asked to rebuild the inorganic characterization capability of BP Amoco Petrochemical after the divestiture of its Olefins and Derivatives division. This led to over \$2M in investment and the modernization of BP's capabilities and methods in elemental analysis, catalyst characterization, X-ray spectroscopy, and microscopy. He now uses these tools to solve problems of interest to BP and consults across BP in these areas. Research highlights include the successful commercialization of Amosorb active barrier additives, development of low viscosity polyester powder coating resins for MDF, development of measurement and QC systems for national QC assurance for low sulfur diesel fuel quality, and, working with Nestor Zaluzec, Grace Burke, and Protochips, the development of the first EDS capable in situ gas and liquid cell technology for TEM/STEM. Dr. Kulzick also coordinates BP research at the Advanced Photon Source at Argonne National Laboratory and serves as a member of the advisory committee for the Center for Functional Nanomaterials at Brookhaven National Laboratory.

Matthew Kulzick
Senior Research Chemist
BP Amoco Chemical Company



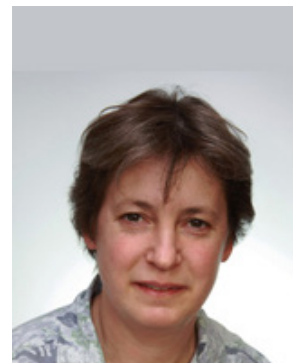
October 10, 2018

Imaging and Controlling Nanoscale Crystal Growth in the Transmission Electron Microscope

Abstract: Building functional nanostructures with atomic level precision requires a detailed understanding of materials growth and the physics of self-assembly at the nanoscale. In situ imaging in the transmission electron microscope can provide unique information by measuring individual nanostructures while they grow. Here we describe examples in which in situ electron microscopy helps explore growth mechanisms and suggests strategies to build new types of structure. We will show nanocrystal epitaxy on graphene, electrochemical deposition processes in aqueous solutions and the formation of semiconductor structures from catalytic droplets. We conclude with a perspective on the exciting recent advances in electron microscopy and how these developments will impact in situ experiments in the future.

Biography: Frances M. Ross received her B.A. in Physics and Ph.D. in Materials Science from Cambridge University. Her postdoc was at AT&T Bell Laboratories, using in situ electron microscopy to study silicon oxidation and dislocation dynamics. She joined the National Center for Electron Microscopy, Lawrence Berkeley National Laboratory, where she imaged anodic etching of Si. She then moved to the IBM T. J. Watson Research Center where she built a program around a microscope with deposition and focused ion beam capabilities and developed liquid cell microscopy to image electrochemical processes. She recently joined the faculty at the Department of Materials Science and Engineering, MIT. Her interests include nanostructure self-assembly, liquid cell microscopy, epitaxy and electrochemical processes. She has been a Visiting Scientist at Lund University and an Adjunct Professor at Arizona State University. She received the UK Institute of Physics Boys Medal, the MSA Burton Medal and MRS Outstanding Young Investigator and Innovation in Materials Characterization Awards, holds an Honorary Doctorate from Lund, and is a Fellow of APS, AAAS, MRS, MSA, RMS and AVS.

Frances M. Ross
Professor
Department of Materials Science
and Engineering, MIT



An Electron Walks Into a Bar... Electron Microscopy Beyond Imaging

Abstract: Electron microscopy techniques play a critical role in understanding structure on the nanoscale; due to recent advances in electron optics and computational tools required to operate the equipment and analyze results, the last decade has been the most exciting period of electron microscopy since the first transmission electron microscope (TEM) was built by Ernst Ruska in 1933. The atomic-scale study of interfaces and surfaces, imaging of individual dopant atoms in crystals, or detection of phonons are just some of the recent scientific breakthroughs enabled by electron microscopy. These previously unmanageable experiments have opened up new fields at the forefront of materials science, physics and beyond.

In addition to improved resolution, the recent hardware advances have also shifted the focus on new and advanced spectroscopic techniques beyond imaging. Due to a range of complex elastic and inelastic scattering events between high-energy electrons and atoms within a material, multiple signals – including x-rays, light, current etc. – are generated inside an electron microscope. In this talk, I will cover several recent examples in which we used MIT-unique electron microscopy methods to collect a range of signals to gain a comprehensive picture of the material's physical properties. Examples include GaN-based light emitting diodes and organic-inorganic perovskite solar cells (PSCs). We used electrons inside an electron microscope to mimic conditions of an operating solar cell device. This process enabled us to directly study changes within the material when exposed to electrons. By using cathodoluminescence and electron beam induced current, we observed point defect migration in PSC devices, but also demonstrated that it can be inhibited by growth of large grain perovskite materials.

Biography: Silvija Gradečak is a (Full) Professor of Materials Science and Engineering at MIT. After receiving her M.S. in Physics from the University of Zagreb in 1999, she obtained her Ph.D. in Physics at the Swiss Federal Institute of Technology in Lausanne and subsequently was awarded the Swiss National Science Foundation Fellowship for Prospective Researchers. After spending 2 years as a Postdoctoral Research Fellow at Harvard University, Professor Gradečak joined the MIT faculty in September 2006. Professor Gradečak's interdisciplinary research program is based on synthesis of materials with confined dimensions – including two dimensional films, one dimensional nanowires/nanotubes, and zero dimensional nanocrystals – and their assembly into functional devices for applications in nanophotonics, nanoelectronics, and in energy harvesting and conversion. To address some of the key challenges in the field of nanomaterials, she combines a set of unique synthesis and characterization techniques with robust material models and device fabrication. Professor Gradečak received several awards including NSF CAREER Award, 3M Innovation Award, Inaugural 2012 Nano Letters Young Investigator Lectureship, and Graduate Materials Council Outstanding Teaching Award.

Sylvija Gradečak
Professor
Department of Materials Science
and Engineering, MIT



October 10, 2018

Compact Synchrotron Radiation Sources Enabling Advanced X-ray Imaging and Diffraction Methods in a Laboratory Setting

Abstract: X-rays are the most important probe for determining the structure of materials from the atomic to the macroscopic scale. Over recent decades, the availability of large-scale synchrotron radiation sources has transformed x-ray diffraction and imaging technologies by providing x-ray beams which are ten or more orders of magnitude more brilliant than typical laboratory-scale x-ray tubes. The existence of only a few remotely located synchrotron facilities, the fact that laboratory-scale sources have not improved significantly, and the large gap in their capability compared with synchrotron sources, has greatly limited the impact of x-ray studies of materials. Having been the founding director of the major US synchrotron facility, the Advanced Photon Source at Argonne National Laboratory, I am well aware of the extraordinary capabilities of the large-scale facilities, as well as the limitations many researchers face in trying to carry out x-ray research within the remote user-facility paradigm. In this talk I will describe the technical opportunities currently being pursued to bring synchrotron radiation capabilities to a laboratory-scale environment. Inverse Compton scattering, in which a laser field replaces the undulator in a conventional synchrotron, allows electrons of much lower energy to produce high-brilliance x-ray beams. As a result, a machine of compact footprint and modest cost can provide x-rays for applications which are not convenient or are actually impossible at a large remote synchrotron user facility. Such technologies could have major impact in university and industrial laboratories.

Biography: David Moncton is director of the MIT Nuclear Reactor Laboratory and Adjunct Professor of Physics. Moncton's research interests lie in two primary categories: (1) x-ray and neutron scattering studies of novel states of matter, and (2) the development of new facility concepts and experimental techniques for producing and using photon and neutron beams. In 1985, his magnetic x-ray diffraction work was named the Outstanding Scientific Accomplishment in Solid State Physics in the Department of Energy's Materials Research Competition. He received the Department of Energy's Ernest Orlando Lawrence Memorial Award in 1987 for his development of high-resolution synchrotron x-ray scattering techniques and their applications.

Moncton served on a study group of the American Physical Society on Boost Phase Intercept for National Missile Defense, which won the 2005 APS Leo Szilard Award. He was a recipient of Argonne's Compton Award in 2013 for development of top-up operation of synchrotron storage rings. He is a Fellow of the American Physical Society, and a Fellow of the Neutron Scattering Society of America. Before joining Argonne, Moncton was a senior research associate at Exxon Research, a group leader at Brookhaven National Laboratory and a member of the technical staff at Bell Laboratories. He holds a B.S. in engineering from Cornell University, and an M.S. and Ph.D. in physics from the Massachusetts Institute of Technology.

David E. Moncton
Director
Nuclear Reactor Laboratory, MIT

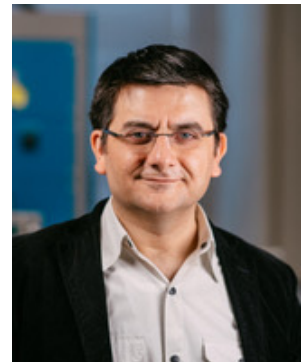


Nanoscale Insights for Macroscale Solutions: Exploring Novel Damage-Resistance Mechanisms in Metals

Abstract: To design metals that have improved property combinations, nanoscale insights of transformation, elasticity, plasticity, damage micro-mechanisms are needed. To this end, we develop various in-situ characterization tools and methods, and use the improved understanding we gain to design new steels, high entropy alloys, titanium alloys.

Biography: Prof. C. Cem Tasan is the Thomas B. King Career Development Professor of Metallurgy, in the Department of Materials Science and Engineering at MIT. He received his BSc and MSc degrees from the Metallurgical and Materials Engineering Dept. of METU, Ankara/Turkey. He then moved to Eindhoven/Netherlands, to carry out his Ph.D. within the group of Professor Marc Geers in the Mechanical Engineering Department of Eindhoven University of Technology. Following his Ph.D. degree in 2010 he moved to Dusseldorf/Germany, for a 2-year post-doc position with Professor Dierk Raabe in Max-Planck-Institut für Eisenforschung (MPIE). He was then appointed in MPIE as a Group Leader, leading the Adaptive Structural Materials group until joining MIT in January 2016. Professor Tasan's research explores the boundaries of physical metallurgy, solid mechanics, and in-situ microscopy, in order to provide environment-friendly metals solutions.

Cem Tasan
Professor
Department of Materials Science
and Engineering, MIT



October 10, 2018

Accelerating the Pace of Materials Characterization at the Atomic Scale: From Machine Learning to Novel Detectors

Abstract: In this talk, I will highlight a number of scanning transmission electron microscopy (STEM) developments that have provided new insights into material properties and have the potential to dramatically accelerate materials characterization. While STEM provides direct imaging of atomic structure, accurate and precise measurements had been prevented by sample drift and scan distortion. To address this limitation, I will discuss our revolving STEM (RevSTEM) solution. The method achieves sub-0.1% accuracy and picometer level precision and enables the direct analysis of local structure without significant computational overhead. Case studies will be presented to demonstrate the capabilities of this technique to accurately characterize the atomic structure of bulk, thin film, and nano materials. I will also discuss our work on implementing artificial intelligence to realize the self-driving electron microscopy. Towards this objective, I will show how we use convolutional neural networks (CNN), which are integral to self-driving cars and face detection, to measure and identify areas of interest in real-time at the microscope. For example, local specimen thickness and tilt can be determined and used to guide the microscope to optimum conditions needed for atomic resolution imaging. Our trained CNN is found to be highly accurate and precise, to within 1-2 nm, fully automatic, and orders of magnitude faster than other approaches.

Biography: James LeBeau is Associate Professor of Materials Science & Engineering at North Carolina State University. He will be joining the Department of Materials Science & Engineering at MIT in Winter 2019. James earned his B.S. in Materials Science & Engineering from Rensselaer Polytechnic Institute in 2006 and his Ph.D. from the University of California Santa Barbara in 2010. He joined the Department of Materials Science and Engineering at North Carolina State University as a faculty member in January 2011 and was promoted to Associate Professor in 2016. His research focuses on applying and developing (scanning) transmission electron microscopy techniques to determine the atomic structure and chemistry of defects/interfaces and connect these to properties of materials for power electronics, dielectrics, and optical applications. He has published over 80 peer reviewed articles and has received a US patent for his unique imaging method. For his research, he has been recognized with numerous awards including the NSF CAREER award, an AFOSR Young Investigator grant, a MAS Distinguished Scholar award, the Birks Award, and the MAS K.F.J Heinrich award.

James LeBeau
Associate Director
Analytical Instrumentation
Facility, NCSU



Using Quantum Mechanics to Hack the Electron Microscope

Abstract: When an electron enters a material, it can either deposit energy directly through coulombic interaction with the particles in the substrate, or indirectly by emitting plasmons and secondary electrons. Both of these processes are responsible for radiolytic damage to samples. They also induce collapse of the quantum-mechanical wavefunction of the electron through coupling to an effective bath of phonon and coupled electron states in the material. Typically, the resulting damage makes nanometer-length-scale imaging of sensitive biological specimens in-vivo impossible.

Recently, quantum non-demolition techniques have been proposed that may permit sensing of a sample state without collapse of the electron wavefunction (and the con-commensurate damage) in certain conditions. By demonstrating a coherent electron resonator in which these quantum non-demolition techniques are used, we hope to develop tools and techniques for engineering the wavefunction of electrons in free space. We will also discuss the possibility that a quantum-electron microscope might one day permit nanometer-length-scale imaging of live biological specimens. Finally, we will touch on electron-exposure mechanisms at play in sub-10-nanometer lithography that help illustrate the damage mechanisms existing in radiolytic samples at this length scale.

Biography: Professor Berggren is Professor of Electrical Engineering at Massachusetts Institute of Technology, Department of Electrical Engineering and Computer Science, where he heads the Quantum Nanostructures and Nanofabrication Group. He is also Director of the Nanostructures Laboratory in the Research Laboratory of Electronics and is a core faculty member in the Microsystems Technology Laboratory (MTL). From December of 1996 to September of 2003, Professor Berggren served as a staff member at MIT Lincoln Laboratory in Lexington, Massachusetts, and from 2010 to 2011, was on sabbatical at the Technical University of Delft in the Netherlands. Professor Berggren is a fellow of AAAS, fellow of IEEE and a fellow of the International Society for Nanomanufacturing. He is a Kavli fellow, and a recipient of the 2015 Paul T. Forman Team Engineering Award from the Optical Society of America. In 2016, he received a Bose Fellowship and was also a recipient of the EECS Department's Frank Quick Innovation Fellowship. He is currently the section editor for patterning and nanofabrication of the IOP Nanotechnology journal, and also serves on the editorial board of the IOP Nano Futures journal. He was the program chair of the 2014 Electron, Ion, Photon Beams and Nanofabrication Conference. From 2008 to 2014 he was an elected member of the board of the Applied Superconductivity Conference. Professor Berggren has served as a consultant to a number of industrial, academic, and government organizations, and continues an active independent consulting practice.

Karl Berggren
Professor
Department of Electrical Engineering
& Computer Science, MIT



October 10, 2018

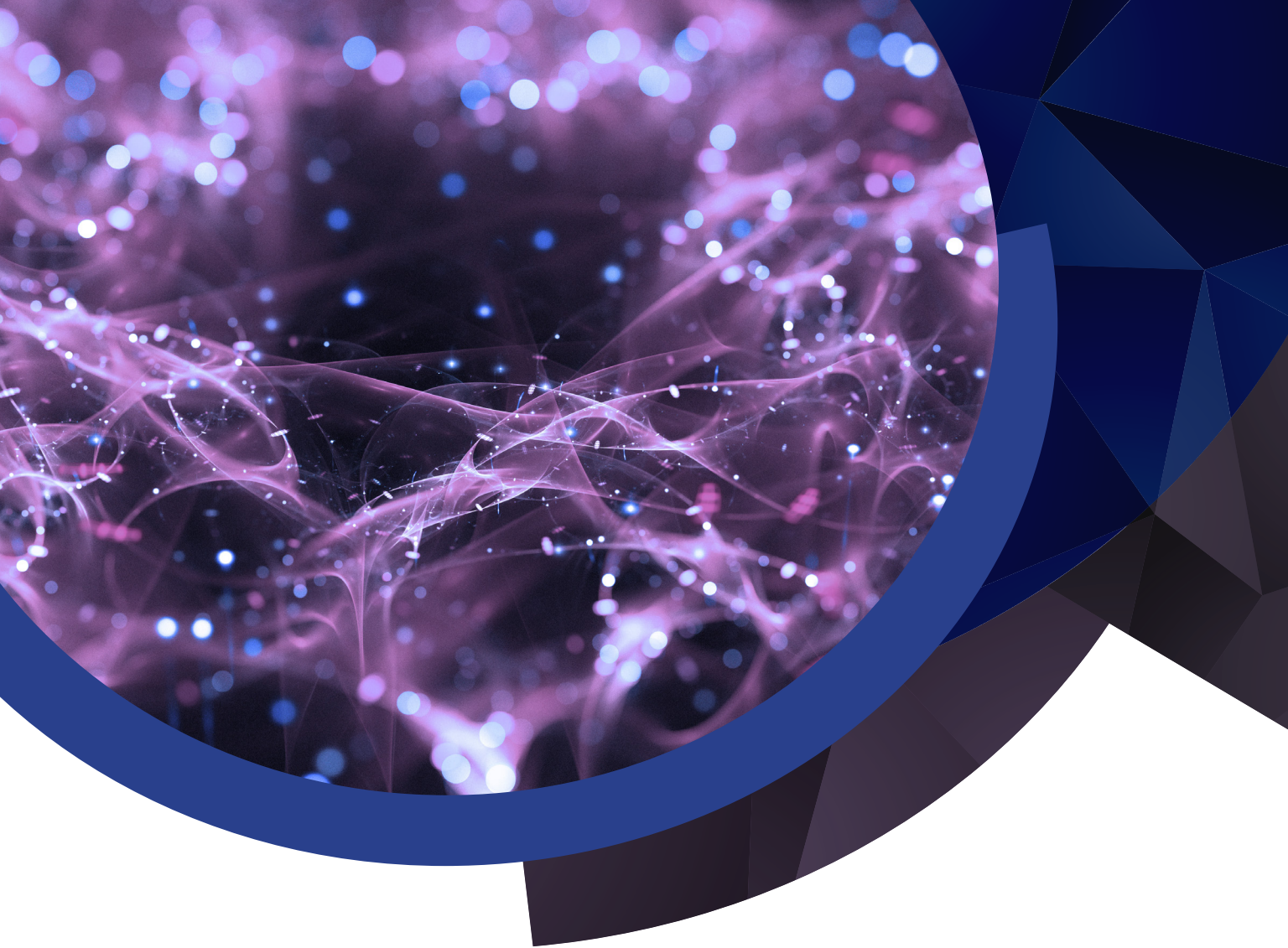
Kresge Auditorium - W16 Stratton Student Center - W20



Date for next years Materials Day event:

October 9, 2019





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