MIT INDUSTRIAL LIAISON PROGRAM ILP

MIT Industry Brief

MIT and Materials Industries

MIT's Industrial Liaison Program (ILP) can bring the intellectual power of MIT to your organization by providing a direct connection to the knowledge, experience and resources at MIT in these areas – giving you the ideas to stay ahead. For more information about how the ILP can put the resources of MIT to work for you, call us at 1-617-253-2691, e-mail us at liaison@ilp.mit.edu, or visit http://ilp.mit.edu.

MIT and Materials Industries

The Massachusetts Institute of Technology (MIT) is a leading center of research and education on topics important to materials industries such as:

- *Advanced Materials, New Materials Development*
- *Biomaterials, Bioprocessing*
- *Building- and Construction-related Materials*
- *Materials Analysis, Characterization, Modeling, Simulation*
- *Materials Behavior, Mechanics*
- *Materials Selection, Fabrication, Processing*
- *Materials and Electronics, Photonics, Semiconductors*
- *Polymer Science and Engineering*
- *Nanomaterials, Nanoscience, Nanotechnology*
- *Manufacturing Technology and Systems*
- *Environmental and Sustainability Issues*

Below are brief descriptions of a selection of MIT centers, departments, groups, and labs conducting research and education in these areas. Please note that this is not a comprehensive summary of research being conducted at MIT in the topic areas listed above and the center or lab, etc., may fall into more than one category.

ADVANCED MATERIALS, NEW MATERIALS DEVELOPMENT

The ***ab initio Physics Group*** researches a variety of complex systems from an ab initio standpoint. The group designs, fabricates, and characterizes photonic crystals for various applications from enhanced lasing to energy harvesting.

The ***Center for Excitonics*** works to develop the science and technology of excitons, to reveal the fundamental characteristics of these crucial quasi-particles, and enable new solar cells and lighting technologies.

The ***Center for 21st Century Energy*** focuses on technologies for efficient and clean energy conversion and utilization, aiming to meet the challenges of rising energy demands and prices, and the concomitant environmental impact.

The ***MIT/MTL Gallium Nitride (GaN) Energy Initiative (MIT-GaN)*** explores advanced technologies and strategies that enable GaN-based materials, devices, and systems to provide breakthrough capabilities for a variety of applications ranging from RF power amplification, to energy processing and power management, as well as advanced optoelectronics.

The ***MIT/MTL Center for Graphene Devices and 2D Systems (MIT-CG)*** explores advanced technologies and strategies that enable graphene-based materials, devices and systems to provide breakthrough capabilities for applications ranging from energy generation and smart fabrics and materials, to RF communications, sensing, or water purification.

The ***Materials Processing Center (MPC)*** research covers the full range of advanced materials, processes, and technologies including: electronic materials; batteries and fuel cells; polymers; advanced ceramics; materials joining; composites of all types; photonics; electrochemical processing; traditional metallurgy; environmental degradation; materials modeling; materials

systems analysis; nanostructured materials; magnetic materials and processes; biomaterials; and materials economics.

The ***NECSTlab (Nano-Engineered Composite aerospace STructures)*** group's interests span fundamental materials synthesis questions through to structural applications of both hybrid and traditional materials. Applications of interest include enhanced (aerospace) advanced composites, multifunctional attributes of structures such as damage sensing, and also microfabricated (MEMS) topics.

MIT ***Photovoltaics Research Laboratory*** research is focused in the areas of crystalline silicon (increased solar conversion efficiency), thin film (tin sulfide, cuprous oxide), and next-gen approaches (hyperdoped silicon).

The ***Extreme Electrochemistry Group*** works toward establishing the scientific underpinnings for technologies that make efficient use of energy and natural resources in an environmentally sound manner, focused on thin film polymer batteries, liquid metal batteries, and multivalent batteries.

BIOMATERIALS / BIOPROCESSING

The ***Bioelectronics Group*** is working at the interface of materials science, electronics and biology. The group's interests are focused on two main goals: Developing of minimally invasive approaches and devices for cell manipulation; and using biological molecules as prototypes and building blocks for optoelectronics.

The ***Laboratory for Bio-Inspired Interfaces (LBI)*** studies bio-inspired materials with the goal of employing design principles extracted from nature in the development of novel synthetic materials that help overcome global challenges in energy, the environment and health.

The ***Biomolecular Materials Group*** evolves simple organisms using directed evolution to work with the elements in the rest of the periodic table. These hybrid organic-inorganic electronic and magnetic materials have been used in applications as varied as solar cells, batteries, medical diagnostics and basic single molecule interactions related to disease.

The ***Cellular Solids Group*** does both modeling and mechanical testing on a wide range of cellular solids. Projects examples: the structure and mechanics of balsa for sandwich panels; structural bamboo products; composite aerogel panels; engineering honeycombs and forms; cellular materials in medicine.

The ***Micro/Nanofluidic BioMEMS Group***'s focus areas include micro / nanofluidics, nanofluidic biomolecule separation and detection, and nanostructure-biomolecule interactions.

The goal of the ***Department of Biological Engineering (BE)*** is to develop effective biology-based technologies for application across a broad spectrum. Research areas include: Biomaterials; biophysics; cell & tissue engineering; energy; environment; microbes; microdevices; molecular therapeutics; nanotechnology; pharmacology; synthetic biology; systems biology; toxicology.

BUILDING- AND CONSTRUCTION-RELATED MATERIALS

The ***Building Technology Program*** is an interdisciplinary program that includes teaching and applications of the fundamentals of technology as well as research on building ventilation and diagnostics; building energy studies; building materials and construction; evaluation of sustainable options; daylighting; structures.

The ***MIT Concrete Sustainability Hub (CSHub)*** is dedicated to improving the sustainability of concrete production and use. Research at the CSHub is focused on three main platforms of concrete: Materials science; buildings and pavements; and economics and environment.

The ***Digital Design Fabrication Group*** is focused on digital delivery of small buildings as kits of parts. The group explores questions related to digital manufacturing, computation, prototyping and materials processing as part of a design process.

The ***Self-Assembly Lab*** is a cross-disciplinary research lab at MIT inventing self-assembly and programmable material technologies aimed at reimagining construction, manufacturing, product assembly and performance.

Civil & Environmental Engineering (CEE): Mechanics and Materials research centers on developing new materials; the nondestructive evaluation of structures; the repair and retrofit of structures using advanced plastic composites; and synthesis and evaluation of innovative designs.

MATERIALS ANALYSIS, CHARACTERIZATION, MODELING, SIMULATION

The ***Computational and Experimental Design of Emerging materials Research Group (CEDER)*** aims to better design high quality functional materials by mapping the relationship between materials structures and their physical and chemical properties by combining computational approaches in quantum mechanics, solid-state physics and statistical mechanics, with selected experiments to investigate materials in the energy field.

The ***Center for Materials Research in Archaeology and Ethnology (CMRAE)*** draws upon the latest analytical methods in biological, chemical, geological, physical, and materials science, to research: ancient environments and ecologies, including site formation and paleodiets; and material culture, or artifact analysis.

Research in 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.

The ***Materials Physics for Materials Design Group*** works at the intersection of fundamental materials physics and computational design of structural materials. The group has developed a research strategy built on "reduced order mesoscale models" (ROMMs), enabling multiscale simulations, tailored experiments, and physics-based design of structural materials.

The ***Laboratory for Atomistic and Molecular Mechanics*** focuses on understanding the mechanics of deformation and failure of biological materials. By utilizing a computational materials science approach, the group's goal is to understand the mechanics of deformation and failure of biology's construction materials at a fundamental level.

MATERIALS BEHAVIOR, MECHANICS

Center for Bits and Atoms (CBA) studies how to turn data into things and things into data. Example CBA projects: have led to advances at the boundary between bits and atoms including what were among the first complete quantum computations; physical one-way cryptographic functions, implemented by mesoscopic light scattering; recoding the genome; and the additive assembly of functional digital materials.

Hatsopolous Microfluids Laboratory (HML) research activities are focused on understanding the dynamics of fluid with microstructure and the science of microfluidics, such as optical imaging of complex flows; rheology and dynamics of complex fluids; flow in microfluidic devices and 'lab-on-a-chip' applications; biofluid mechanics and biorheology.

The ***Laboratory for Material Chemomechanics*** develops experimental and computational approaches toward the understanding of the coupling between the mechanical and structural/functional states. The lab develops several enabling nanomechanical frameworks such as nano/picoindentation, atomic force microscopy and functional force imaging.

The ***Nanomechanics Laboratory*** investigates mechanical properties of engineered and biological materials at the nano- to macro-scale using experimental, analytical, and computational techniques. Projects include studies of nanostructured materials as well as exploring connections between biological cell mechanics and human disease states.

The ***Plasma Science and Fusion Center (PSFC)*** is focused on the scientific and engineering aspects of magnetic confinement fusion and related plasma science and technology. Non-fusion applications are numerous and diverse as well, addressing plasma-based technologies, including environmental remediation and hydrogen production.

The ***Soft Active Materials Laboratory*** seeks to design soft materials with unprecedented properties (i.e., extremely tough and strong, ultrasensitive to stimuli, mutable, biocompatible, etc.) and to explore their extraordinary functions in technologies such as wearable and biointegrated electronics, drug delivery and tissue engineering, antifouling, energy harvesting and storage, water treatment.

The ***H.H. Uhlig Corrosion Lab*** investigates the causes of failure in materials and the prevention of failure in materials, with an emphasis on nuclear materials. The lab has the ability to test and analyze failure modes of any material related to nuclear engineering in the fields of fission, fusion and nuclear research, and can carry a project from concept through execution and analysis with the facilities on site.

Research in the ***Department of Materials Science and Engineering (DMSE)*** ranges from the purely scientific to applied studies, and involves perspectives of chemistry, physics, electronics, the artistic and historical aspects of materials, design, and entrepreneurial ventures. Interests span the entire materials cycle from mining and refining of raw materials, to production and utilization of finished materials, to disposal and recycling.

MATERIALS SELECTION, FABRICATION, PROCESSING

The ***Magnetic Materials and Devices Group*** carries out research in thin film magnetism, magnetic device, and self-assembly. Research area examples: magnetic devices for memory and logic; magnetooptical materials for integrated photonic devices; templated self-assembly of block copolymers for nanolithography; templated self-assembly of heterostructured oxide.

Materials Systems Laboratory (MSL) studies the competitive position of materials in specific applications (assessment of candidate materials and process technologies; evaluation of the economic and non-economic consequences of each alternative) toward developing tools useful at an early stage of product design. Methodologies include technical cost modeling, lifecycle cost and emissions tracking, decision analysis techniques, systems dynamics modeling, and system cost modeling.

The ***Metals Lab @ MIT*** is where students expand their applied material knowledge through hands-on coursework in the metalworking facilities, which include the forge and foundry. Students learn the basics of materials processing through classic techniques, while simultaneously discovering how new technologies like 3D printing can be integrated into a traditional process.

The ***Department of Mechanical Engineering (MechE)*** conducts research in a range of areas—mechanics, product design, energy, nanoengineering, ocean engineering, control, robotics, bioengineering, which lead to results in a variety of innovative projects, including the prevention of material degradation in proton-exchange membrane fuel cells; fabrication of 3-D nanostructures out of 2-D substrates; use of active control to optimize combustion processes; the development of unmanned underwater vehicles; and the development of physiological models for the human liver.

MATERIALS & ELECTRONICS, PHOTONICS, SEMICONDUCTORS

The ***Center for Materials Science and Engineering (CMSE)*** fosters research and education in the science and engineering of materials. Example research areas: Harnessing in-fiber fluid instabilities for scalable and universal multidimensional nanosphere design, manufacturing, and applications; simple engineered biological motifs for complex hydrogel function; nanoionics at the interface: charge, phonon, and spin transport.

The ***Electronic Materials Research Group at MIT (EMAT)*** explores silicon-based microphotonics. The group's focus is materials processing and device engineering for the creation of micron and sub-micron scale device elements for vertical integration with circuit systems. Primary applications include telecommunications, computation, and imaging.

The ***Microphotonics Center (MPhC)*** is a research community in which industry, government, and academia collaborate to create new materials, structures, and architectures for the emerging microphotonics platform—the menu of on-chip and circuit-board level devices and components that will comprise future optoelectronics for telecommunications, computing, and sensing.

The ***Microsystems Technology Laboratories (MTL)*** supports microsystems research encompassing work in circuits and systems, MEMS, electronic and photonic devices, and molecular and nanotechnology. MTL research is enabled by a set of shared experimental facilities, as well as the Microsystems Industrial Group (MIG), and is home to the Center for Integrated Circuits and Systems, Medical Electronic Device Realization Center, Center for Graphene Devices and 2D Systems, and the Gallium Nitride (GaN) Energy Initiative.

The ***Research Laboratory of Electronics' (RLE)*** major research themes include: Atomic Physics; Biomedical Science & Engineering; Energy, Power, and Electromagnetics; Information Science & Systems; Nanoscale Materials, Devices & Systems; Photonic Materials Devices and Systems; and Quantum Computation & Communication.

The ***RLE Organic and Nanostructured Electronics (One Lab)*** studies the physical properties of organic thin films, structures, and devices. The group's fundamental findings are applied to the development of practical optoelectronic, electronic, and photonic organic devices of nano-scale thickness, including visible LEDs, lasers, solar cells, photodetectors, transistors, chemical sensors, and memory cells.

The ***RLE fibers @ mit*** group focuses on extending the frontiers of fiber materials from optical transmission to encompass electronic, optoelectronic, and even acoustic properties. Two complementary approaches towards realizing sophisticated functions are utilized: the integration of a multiplicity of functional components into one fiber, and the assembly of large-scale fiber arrays and fabrics.

The ***RLE Quantum Nanostructures and Nanofabrication Group*** is focused on pushing nanofabrication technology to the few-nanometer length-scale by using charged-particle beams combined with self-assembly. The group uses the technologies developed to push the envelope of what is possible with photonic and electrical devices, focusing in particular on the nanowire-based superconductive photodetectors.

The ***RLE Soft Semiconductor Group***'s work spans two applications—optoelectronics and digital logic. The optoelectronics focus includes organic light-emitting devices and low-cost solar cells. For logic, the group's focus is on building systems using spintronics to overcome power dissipation, perhaps the greatest weakness of conventional field-effect transistor logic.

The ***Advanced Semiconductor Materials & Devices Group*** focuses on advanced electronic devices based on new semiconductors, especially nitrides and graphene, and is using

these semiconductors in: High frequency electronics (>300 GHz); high voltage electronics (600 V – 10 kV) for power conversion; digital electronics in a post-Si scenario; and new concepts for biosensors and energy harvesting devices.

POLYMER SCIENCE & ENGINEERING

The ***Program in Polymers and Soft Matter (PPSM)*** is an interdisciplinary program offering graduate education in polymer science and engineering. PPSM produces a popular weekly research seminar, coordinates the schedules of visitors to MIT from the worldwide community of polymer specialists in industry, academia and government, and arranges special events and research poster competitions for the MIT polymer community.

The ***Bioinspired and Biofunctional Polymers Group***'s research in polymer science attempts to understand the statistical mechanics, thermodynamics, and transport properties of these large molecules and to apply this understanding to the intelligent design of biofunctional and bioinspired polymeric materials with new and interesting properties for applications in biotechnology, energy, and sustainability.

The ***Engineering Multifunctional Polymeric Nanomaterials Group*** focuses on the self-assembly of polymeric nanomaterials, with a major emphasis on the use of electrostatics and other complementary interactions to generate multifunctional materials with highly controlled architecture. The uniting theme of the lab: the understanding and use of secondary interactions to guide materials assembly at surfaces and in solution.

The ***Laboratory for Theoretical Soft Materials*** uses theory and computer simulations to understand a variety of soft matter systems. The group's work largely concentrates on the self-assembly and dynamics of systems ranging from single chain polymers, block copolymers, lipid bilayers, colloids, and polymer brushes.

MIT's ***Chemical Engineering Department (ChemE)*** research projects fall into at least one of nine broad areas: Thermodynamics and molecular computations; catalysis and reaction engineering; systems design and engineering; transport processes; biological engineering; materials; polymers; surfaces and structures; and energy and environmental engineering.

NANOMATERIALS / NANOSCIENCE / NANOTECHNOLOGY

The ***Institute for Soldier Nanotechnologies (ISN)*** team of MIT, Army, and industry partners collaborate to create new materials, devices, processes, and systems, and on applied research to transition promising results toward practical products useful to the soldier. ISN research is organized into five strategic areas: Lightweight, multifunctional nanostructured materials; soldier medicine; blast and ballistic threats—materials damage, injury mechanisms, and lightweight protection; hazardous substances sensing; and nanosystems integration.

The ***Materials for Micro- and Nano-Systems Group*** carries out research on thin films and nanostructures for use in micro- and nano-systems, especially electronic, electromechanical and electrochemical systems. The group does basic research on stress and structure evolution during growth of polycrystalline films, and on solid-state dewetting of thin films; carbon nanotubes are used in ongoing research on Li-air batteries and nanowires are used in Li-ion batteries.

The ***RLE Nanomaterials and Electronics Group*** is designing new strategies to make graphene, MoS2, h-BN, and other novel 2D materials with desired physical, chemical qualities. The in-depth understanding in how to make those materials enables the group to develop brand new architectures for high-performance electronics and energy conversion.

The ***Laboratory for Nanophotonics and Electronics*** focuses on nano-photonics and electronics and is based on the synthesis, characterization and integration of low-dimensional systems. By taking the advantage of unique material properties on the nanoscale, the lab explores novel optoelectronic applications such as nanoscale light-emitting sources, single photon sources, or nanowire lasers.

The ***NanoStructures Laboratory (NSL)*** develops techniques for fabricating surface structures with feature sizes in the range from nanometers to micrometers, and uses these structures in a variety of research projects. Research projects: development of nanostructure fabrication technology; nanomagnetics, microphotonics and templated self assembly; periodic structures for x-ray optics, spectroscopy, atomic interferometry and nanometer metrology.

The ***Space Nanotechnology Laboratory's (SNL)*** expertise is in the fields of nanofabrication, nanometer-accuracy x-ray optics fabrication, assembly and metrology, ultra-high resolution lithography, nanometrology, and nano-accuracy diffraction grating fabrication.

MANUFACTURING TECHNOLOGY & SYSTEMS

The ***Sustainable Materials Extraction & Manufacturing Group*** investigates the development of a new electrochemical route for metals production in extreme environments (molten sulfides or rare-earth oxides); the direct forming of alloys by electrochemical techniques in collaboration with a large end-

user of precious metals toward providing a manufacturing tool that eliminates numerous unit-operations; and is pursuing an understanding of the minerals leaching process from a chemical and materials science viewpoint.

The ***Laboratory for Manufacturing and Productivity (LMP)*** is an interdepartmental laboratory dedicated to the development and application of the fundamental principles of manufacturing systems, processes, and machines. Research and education is focused in the areas of design, analysis, and control of manufacturing processes and systems.

ENVIRONMENTAL & SUSTAINABILITY ISSUES

The ***Center for Clean Water and Clean Energy at MIT and KFUPM*** focuses on research in desalination, low carbon energy, related areas of design and manufacturing as well as curriculum development in mechanical engineering. Projects are in the areas of clean energy, clean water, and design.

The ***Environmentally Benign Manufacturing (EBM)*** group is focused on examining the environmental impacts of the product lifecycle, and focused on the design, manufacturing, and end-of-life stages. Research areas: the thermodynamic, economic, and life cycle assessment of manufacturing processes and systems, products and recycling systems, and the environmental effects from the consumption side of the issue.

The ***Solid-State Solar Thermal Energy Conversion (S3TEC) Center*** aims at advancing fundamental science and developing materials to harness heat from the sun and convert this heat into electricity via solid-state thermoelectric and thermophotovoltaic technologies.

The ***Civil & Environmental Engineering: Geotechnical Engineering and Geomechanics*** research group addresses a wide range of problems posed by the spatial variability and complex material properties of soils and rocks. Geoenvironmental problems of subsurface waste containment, groundwater contamination and site remediation are a major focus of the field, as are problems related to resource extraction, including engineered geothermal systems.

The mission of the Massachusetts Institute of Technology is to advance knowledge and educate students and others in science, technology, and additional areas of scholarship. MIT is committed to generating, disseminating and preserving knowledge and to working to bring this knowledge to bear on the world's great challenges. As part of its mission, MIT maintains relationships with industrial organizations that enable the exchange of ideas in the context of real-world problems and demonstrate how principles studied at MIT are applied to generate practical benefits for industry and society. MIT's Industrial Liaison Program helps develop these relationships by facilitating industry's access to MIT and its vast resources.