October 17, 2012

MPC
Making Matter, Matter

Materials Day '12

Materials for Energy Harvesting

Materials Resources:

Materials Processing Center provides an environment where students and professionals from industry, government and academia collaborate to identify and address pivotal multidisciplinary issues in materials processing and manufacturing at MIT.
http://mpc-web.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.
http://mphotonics.mit.edu

The Communications Technology Roadmap (CTR) is a project under the Microphotonics Industry Consortium, which in turn is 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 Solid State Solar-Thermal Energy Conversion Center (S^3TEC) objective is to create novel solid-state materials for the conversion of sunlight and heat into electricity.
http://s3tec.mit.edu

Materials@MIT is a portal website to all materials activities at MIT.
http://materials.mit.edu

Center for Materials Science & Engineering is devoted to the design, creation, and fundamental understanding of materials that are capable of enhancing the human experience.
http://mit.edu/cmse

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

Dates for future Materials Day events:

Wednesday, October 23, 2013

Tuesday, October 21, 2014

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

MATERIALS PROCESSING CENTER

Materials Day at MIT

Materials for Energy Harvesting

October 17, 2012

Materials for Energy Harvesting will be the focus of this year's Materials Day. Material and the performance considerations will be related to piezoelectric, thermoelectric and photonic systems. A range of applications will be addressed including portable devices, sensing, transportation and others. Materials Day activities will include a one-day conference featuring speakers from both inside and outside MIT. A student poster session will follow, featuring 50 to 100 posters with up-to-the-minute research results from the broad materials research communities in MIT's Schools of Engineering and Science.

Materials Processing Center
Massachusetts Institute of Technology
77 Massachusetts Avenue
Room 12-007
Cambridge, MA 02139
http://mpc-web.mit.edu/
email: mpc@mit.edu

Materials Day Agenda

8:00 am	**Registration** (Kresge Auditorium)
8:45 am	**Welcome** Professor Carl V. Thompson Director, Materials Processing Center Department of Materials Science & Engineering, MIT
Session I:	
9:00 am	**Thermoelectrics - A promising material system for solid state power generation, waste heat recovery and thermal management** Dr. Lon E. Bell Founder and Former CEO Amerigon
9:40 am	**Nanostructured Materials for Thermoelectric Energy Conversion** Professor Gang Chen Carl Richard Soderberg Professor of Power Engineering Mechanical Engineering Department, MIT
10:20 am	**Break**
Session II:	
10:40 am	**Materials Challenges of Future Energies** Dr. Sergio Kapusta Chief Scientist for Materials Shell International E&P Inc.
11:20 am	**Glucose Powered Medical Implants** Professor Rahul Sarpeshkar Electrical Engineering and Computer Science Department, MIT
12:00 - 1:00 pm	**Lunch** Student Center, 3rd floor, Twenty Chimneys/Mezzanine Lounge (Bldg. W20)
Session III:	
1:10 pm	**The Piezoelectric MEMS Energy Harvesting: A Reality Soon** Professor Sang-Gook Kim Mechanical Engineering Department, MIT

1:50 pm **Thin-Film PV for Low-Cost Solar**
Dr. Dave Eaglesham
Chief Executive Officer
Pellion Technologies

2:30 pm **Silicon-Based High Efficiency Solar: Technology and Opportunities**
Professor Gene Fitzgerald
Merton C. Flemings SMA Professor of Materials Engineering
Department of Materials Science & Engineering, MIT

3:10 pm **Wrap-up and Discussion with Attendees**

Materials Research Review Poster Session

3:30 pm **Poster Session and Social**
La Sala De Puerto Rico, 2nd Floor Stratton Student Center (Bldg. W20)

5:45 pm **Poster Awards**

6:00 pm **Adjourn**

Professor Carl V. Thompson

Director, Materials Processing Center
Stavros Salapatas Professor of Materials Science and Engineering, MIT

Biography

Professor Carl V. Thompson received his SB in Materials Science and Engineering from the Massachusetts Institute of Technology in 1976. He received his SM and PhD degrees in Applied Physics from Harvard University in 1977 and 1982 respectively. He was an IBM postdoctoral fellow in the Research Laboratory of Electronics at MIT in 1982 and joined the faculty of the Department of Materials Science and Engineering in 1983. He is currently the Stavros Salapatas Professor of Materials Science & Engineering. Professor Thompson spent the 1990-91 academic year at the University of Cambridge Department of Materials Science and Metallurgy, where he was awarded a United Kingdom Science and Engineering Research Council Visiting Fellowship. He spent the 1997-98 academic year at the Max-Plank Institute fur Metallforschung in Stuttgart, Germany as a result of having received an award for Senior U.S. Scientist from the Alexander Von Humboldt Foundation. He was the President of the Materials Research Society in 1996. At MIT, Prof. Thompson currently Co-Chairs the Singapore-MIT Alliance program in Advanced Materials for Micro and Nano-Systems and is the Co-Director of the Iberian Nanotechnology Laboratory-MIT Program. He became the Director of the Materials Processing Center in 2008.

Dr. Lon E. Bell

Founder & Former CEO
Amerigon

Thermoelectrics - A Promising Material System for Solid State Power Generation, Waste Heat Recovery and Thermal Management

Abstract

Thermoelectric systems are direct energy conversion devices for converting thermal flux to electric power, and the reverse, transforming electric power directly to pumping heat from a cold source to a hot heat sink. Thermoelectric devices have been used for over 60 years in aerospace applications where their favorable characteristics of no moving parts, small size and reliability have made them the choice for space craft power generation, laser diode thermal management and amplifier refrigeration in portable night vision systems. The limitations of the technology, low efficiency and relatively high cost per unit of conversion capacity, have prevented TE systems from gaining wider commercial acceptance.

Air conditioning and other cooling systems utilize two-phase refrigerants, a major source of environmental pollutants. These pollutants could be eliminated if thermoelectric systems were to successfully replace today's technology. Similarly, large scale deployment of thermoelectric waste heat recovery systems could replace some fraction of primary power production in combustion systems, such as vehicle engines and fossil fuel fired electric power generators, and hence reduce CO2 emissions.

This presentation reviews the governing equations for thermoelectric materials and the characteristics of thermoelectric systems, and discusses in detail the opportunities to improve performance both from material and system perspectives. The potential and processes to migrate thermoelectrics from its present state to that of a broadly impactful technology platform are discussed. Modest, but specific, advancements from the fields of material science, surface chemistry, nanotechnology, thermodynamics and mechanical engineering would allow thermoelectrics to play a significant role in addressing some of the world's most vexing issues.

Biography

Bell, Ph.D. recently retired from his position as President of BSST LLC, Amerigon Inc.'s research and development subsidiary, a position he had held since September 2000. Bell founded Amerigon in 1993. From Amerigon Inc.'s formation, he was Chief Technology Officer until 2000, Chief Executive Officer until 1999, President until 1997 and a Director from 1991 to 2010. Bell is a leading expert in the design and mass production of thermoelectric products.

In 1991, Bell was a cofounder of Calstart and later Mahindra REVA. Previously, Bell co-founded Technar Incorporated, which developed and manufactured proprietary automotive sensors and controls. Bell served as Technar's Chairman and President until selling majority ownership to TRW Inc. in 1986. Bell continued managing Technar, then known as TRW Technar, as its President until 1991.

Currently he is a member of the boards of directors of Amerigon Incorporated, Mahindra-REVA and ClearSign Combustion Corporation. He is a Member of Scientific Advisory Boards of California Institute of Techology's Mechanical Engineering Department, University of California at Santa Barbara's Institute for Energy Efficiency and Michigan State University's Energy Frontier Research Center, and Alphabet Energy.

Professor Gang Chen

Carl Richard Soderberg Professor of Power Engineering
Mechanical Engineering Department, MIT

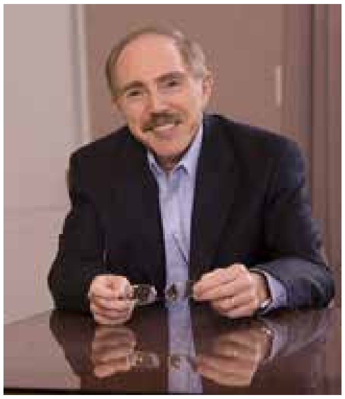
Nanostructured Materials for Thermoelectric Energy Conversion

Abstract

This talk will discuss challenges, progress, and opportunities in thermoelectric energy conversion technology. Thermoelectric energy conversion exploits the Seebeck effect to convert thermal energy into electricity, or the Peltier effect for heat pumping applications. One key issue is to improve materials thermoelectric figure-of-merit that is linearly proportional to the square of the Seebeck coefficient, the electrical conductivity, and inversely proportional to the thermal conductivity. Improving the figure-of-merit requires good understanding of electron and phonon transport as their properties are often contradictory in trends. Excellent progress has been made in materials over the past decade, especially by exploring nanoscale size effects. Taking materials to real world applications, however, faces more challenges in terms of materials stability, device fabrication, and system design. Great opportunities exist in advancing materials as well as in using existing materials for energy efficiency improvements and renewable energy utilization.

Biography

Dr. Gang Chen is currently the Carl Richard Soderberg Professor of Power Engineering at Massachusetts Institute of Technology. He obtained his Ph.D. degree from UC Berkeley in 1993 working under then Chancellor Chang-Lin Tien. He was a faculty member at Duke University (1993-1997), and University of California at Los Angeles (1997-2001), before joining MIT in 2001. He is a recipient of the NSF Young Investigator Award, the ASME Heat Transfer Memorial Award, the R&D100 Award, and the MIT McDonald Award for Excellence in Mentoring and Advising. He is a member of the US National Academy of Engineering, a Guggenheim Fellow, an AAAS Fellow, and an ASME Fellow. He has published extensively in the area of nanoscale energy transport and conversion and nanoscale heat transfer. He is the director of Solid-State Solar-Thermal Energy Conversion Center funded by the US DOE's Energy Frontier Research Centers program.



Dr. Sergio Kapusta

Chief Scientist for Materials
Shell International E&P Inc.

Materials Challenges of Future Energies

Abstract

These are interesting times in the energy business. Global energy demand continues to rise due to improving living standards and population growth. At the same time, the world's remaining supplies of oil and gas are harder-to-find and more difficult to produce. And environmental and social challenges are increasing. The connection between energy production, water consumption and food supply is one example of this challenge.

In my 30-year career in the oil business I have never witnessed a more intense focus on innovation and technology to provide the energy needed today and in the future. This focus does not come at a better time because the challenges that we face can only be resolved by a step change in our thinking: how can we bring the developments in electronics, computing, communications, biotech and materials science to help us develop our energy resources?

This presentation will address some of the materials challenges of the future energies, and pose a few questions to the audience: all new forms of energy from hydrogen to solar, from wind to biofuels, have a higher demand for materials than the conventional fossil fuels. How can we resolve this dilemma? How can we make nano-enhanced materials that have superior performance and affordable costs? How can we develop these alternative energies in a sustainable way?

Biography

Sergio Kapusta is Chief Scientist of the Royal Dutch Shell and Manager of Physics & Materials Research at Shell International E&P, Inc., based in Houston, where he oversees research and development in the areas of materials, corrosion, asset integrity, reliability, energy efficiency, and physical methods of analysis. He is concurrently manager of the Shell Water-Stress Nexus initiative.

He has been employed with Shell Oil Company for 28 years. During this time, he has held positions of increasing responsibility in Research, Engineering and Operations, in all major segments of the oil and gas business: production, transportation, and processing and he has actively led and contributed to the implantation of nanotechnology-based techniques into the oilfield. Sergio has also consulted with major oil and gas companies all over the world in topics of corrosion, risk assessment and materials selection. Among his clients are BP, ExxonMobil, ConocoPhillips, Chevron, PDVSA, Petrobras, Petronas, PetroChina, CNOOC (China), and Repsol-YPF.

Sergio is the author of more than 70 articles and presentations in the areas of electrochemistry, corrosion control, materials, and asset integrity. Sergio is a Distinguished Fellow of NACE International, the Corrosion Society. In 2004 he received the prestigious Technical Accomplishment Award of NACE International. He is a member of SPE and of AIChE, and has held chair roles in various committees of these professional organizations. Additionally, Sergio has been on the staff of Rice University as Lecturer, Researcher and Adjunct Professor since 1983, and is on the Advisory Board of King Abdullah University of Science and Technology, Saudi Arabia.

He received his BS degree in Chemical Engineering from the University of Buenos Aires (Argentina), and his Ph.D. and MBA from Rice University in the US. He and his wife Marta, reside in Houston, Texas.

Professor Rahul Sarpeshkar

Electrical Engineering and Computer Science Department, MIT

Glucose Powered Medical Implants

Abstract

Medical implants such as those for the deaf, blind, paralyzed, or cardiac patients will one day be powered by harvesting energy from glucose in bodily fluids. This talk will discuss how the combination of ultra-low-power electronic design and a novel glucose fuel cell could make such systems practical: The ultra-low-power electronic design achieves performance near the fundamental limits of physics for nerve recording and nerve stimulation via low-noise design and adiabatic energy-recycling techniques; it also utilizes extremely energy-efficient RF telemetry and signal-processing circuits. The glucose fuel-cell design uses roughened platinum to improve glucose oxidation efficiency at the anode and a carbon-nanotube cathode for oxygen reduction. The fuel cell operates without enzymes and only uses proven biocompatible materials making it advantageous for long-life-time implantation in the body. The fuel cell is fabricated in a standard semiconductor fabrication process such that the fuel cell and associated electronics may all be cheaply and simultaneously fabricated.

This work illustrates that low-power systems can enable sources of energy that would normally be impractical for powering an application to become practical. Furthermore, the characteristics of the energy load can alter the design of the energy source that is meant to drive it optimizing energy density or power density. The central take-home lesson from this work and other examples is that energy use and energy generation are deeply linked: We must try to optimize them jointly rather than treat them as two separate problems.

Biography

Rahul Sarpeshkar obtained Bachelor's degrees in Electrical Engineering and Physics at MIT. After completing his PhD at CalTech, he joined Bell Labs as a member of the technical staff in their department of biological computation. He is currently on the faculty of MIT's Electrical Engineering and Computer Science Department, where he heads a research group on Analog Circuits and Biological Systems (http://www.rle.mit.edu/acbs/). He holds over 30 patents and has authored more than 120 publications, including one that was featured on the cover of Nature. His recent book, Ultra Low Power Bioelectronics: Fundamentals, Biomedical Applications, and Bio-inspired Systems discusses how ultra-low-power and energy-harvesting systems may be architected in applications ranging from medical implants for the deaf, blind, and paralyzed to electric cars. He has won several awards for his interdisciplinary bioengineering research including the NSF Career award, the ONR Young Investigator award, and the Packard Fellow award given to outstanding faculty. He was a speaker at the 2011 'Frontiers of Engineering' conference hosted by the National Academy of Engineering. His recent work on a glucose fuel cell for medical implants was featured by BBC Radio, the Economist, and Science News.

Professor Sang-Gook Kim
Mechanical Engineering Department, MIT

The Piezoelectric MEMS Energy Harvesting: A Reality Soon

Abstract

Piezoelectric Microelectromechanical Systems (MEMS) has been proven to be an attractive technology for harvesting small energy from the ambient vibration. This technology will eliminate the need for replacing chemical batteries or complex wiring for microsensors / microsystems. To achieve this goal, an energy harvester at a size of a quarter dollar coin should be able to generate robustly about 100mW continuous power from ambient vibration as well as the cost of the device should be low enough for large-scale deployment. At the present time, most of the devices reported in literature do not meet these requirements and the real application of this technology is still futuristic. This talk reviews the current state-of-the-art with respect to the key challenges toward the real world applications and describes the novel ideas and efforts in piezoelectric materials and resonator structure design which are believed to be the solution to these challenges. Recent advancements in piezoelectric materials and harvester structural design, individually or in combination, have improved MEMS energy harvesters to achieve enough power capacity, compactness and ultra wide bandwidth, bringing us closer towards battery-less autonomous sensors systems and networks in very near future. Non-linear resonating beams for wide bandwidth resonance are the key development to enable robust operation of energy harvesters over the unpredictable and uncontrollable frequency spectra of ambient vibration. Epitaxial growth and grain texturing of piezoelectric materials are developed to achieve much higher energy conversion efficiency. For embedded medical systems, lead-free piezoelectric thin films are being developed. We expect that a coin size harvester will be able to harvest about 100mW continuous power at below 100 Hz, less than 0.5 g vibration and at reasonable cost very soon.

Biography

Sang-Gook Kim joined MIT as an associate professor in 2001, received tenure in 2006, and was promoted to full professor in 2010. He received his B.S. degree from Seoul National University (1978), M.S. from KAIST (1980), and Ph.D. from MIT (1985). He held positions at Axiomatics Co. (1986) and Korea Institute of Science and Technology from 1986-1991. In 1991 he joined Daewoo Corporation, Korea, as a General Manager, and then directed the Central Research Institute of Daewoo Electronics Co. until 2000 as a corporate executive director. He is a fellow of the International Academy for Production Engineering (CIRP) and ASME.

Kim's research and teaching at MIT have addressed issues bridging the gap between scientific findings and engineering innovations, developing novel manufacturing processes for newly-developed materials, and designing and realizing new products at micro- and nano-scales. These include carbon nanotube assembly, muscle-inspired micro-actuators, nano-engineered organic solar cells, piezoelectric MEMS energy harvesters and direct printing of piezo MEMS devices such as piezoelectric micro ultrasonic transducers (PMUTs).

Dr. David Eaglesham

Chief Executive Officer
Pellion Technologies

Thin-Film PV for Low-Cost Solar

Abstract

This talk will outline some of the challenges and opportunities for thin-film PV, based on the author's prior experience at First Solar.

Thin film has easily the best cost/m2 of any PV technology, and a range of materials have been developed with a view to exploiting this for low-cost solar. Recently, the elemental abundance of the raw materials has become a criterion for the development of new PV absorbers. However, as this talk will show, the BOM cost (bill-of-materials) of a solar panel is dominated by glass and other "non-absorber" materials; the cost of the panel is itself largely non-BOM; and the system cost is in turn dominated by non-module contributions. The cost of the absorber itself is a small component of overall system cost, so cost/kWh is driven by PV efficiency. This creates two issues for "earth-abundant solar": the chances of finding "good" when you're looking for "cheap" are not so good; and your new material needs to match current CdTe efficiency before it can start its learning curve.

For TF-PV devices which meet this efficiency target, the prospects for improvement remain extremely attractive. This is again because the cost is dominated by non-absorber costs: band-engineering or multi-junction technologies tend to increase the cost of the semiconductor, but they can increase it enormously before it begins to significantly affect the cost of the device. This opens up enormous opportunities for materials-engineering the absorber to enhance device performance.

Biography

Dave Eaglesham is currently CEO at Pellion Technologies, a start-up working to replace Li-ion batteries with higher-energy-density Mg-ion. Founded by a team of MIT researchers in 2009, Pellion is backed by top-tier venture-capital, with funding from DoE's ARPA-E program. Prior to Pellion, Dr. Eaglesham served as CTO/VP of First Solar for six years and saw the company grow from less than $50M in revenues to be a world-leading manufacturer of thin film PV with close to $4B in revenues, while achieving multiple world records for Cadmium-Telluride (CdTe) cell and module efficiency. He has worked at Lawrence Livermore as Chief Technologist and at Applied Materials as Director of Advanced Technologies. At Bell Labs he worked on semiconductor deposition techniques and doping and rose (or sank) to be VP of Electronic Device Research. He has a Ph.D. in Physics from the University of Bristol and achieved tenure as a Lecturer at Liverpool University before joining Bell Labs in 1988. He was named Outstanding Young Investigator by the Materials Research Society in 1994, was MRS President in 2005, and is a Fellow of the American Physical Society.

Professor Gene Fitzgerald

Merton C. Flemings SMA Professor of Materials Engineering
Department of Materials Science and Engineering, MIT

Silicon-Based High Efficiency Solar: Technology and Opportunities

Abstract

Mature solar is based on silicon (poly and single crystal) and CdTe thin film solar cells. These two high-volume solar cell technologies leverage existing infrastructure created by the LCD and Silicon CMOS industries. However, the economics of solar clearly show that the desire to have low cost solar electricity can be satiated with much higher solar cell efficiencies. Realistically, the physics of high efficiency resides in multi-junction III-V single-crystal epitaxial films. The long-term goal would be to fabricate high efficiency III-V multi-junction cells on silicon in a silicon-manufacturing environment. Despite this logical conclusion, there is little work in this direction. We show not only that III-V/Si is technically possible, but also that niche applications such as solar-powered unmanned aerial vehicles should be the focus application to drive volume, ultimately leading to lower-cost high-efficiency solar electricity in the future.

Biography

Eugene A. Fitzgerald is the Merton C. Flemings SMA Professor of Materials Engineering at the Massachusetts Institute of Technology. Building upon his early experience at AT&T Bell Labs which included the invention of high mobility strained silicon, he has created fundamental innovations in stages from early technology to final implementation in the market. His research interests include novel thin film materials and devices. He is founder, co-founder or founding team member of AmberWave Systems Corporation, Contour Semiconductor, 4Power LLC (high efficiency III-V solar on silicon), Paradigm Research LLC, and The Water Initiative. He is co-author of "Inside Real Innovation", published internationally in January of 2011. He is recipient of the IEEE 2011 Andrew S. Grove Award, the IEEE 2004 EDS George Smith Award, and the TMS 1994 Robert Lansing Hardy Medal Award. He received a B.S. degree in Materials Science and Engineering in 1985 from MIT and his Ph.D. in the same discipline from Cornell University in 1989.

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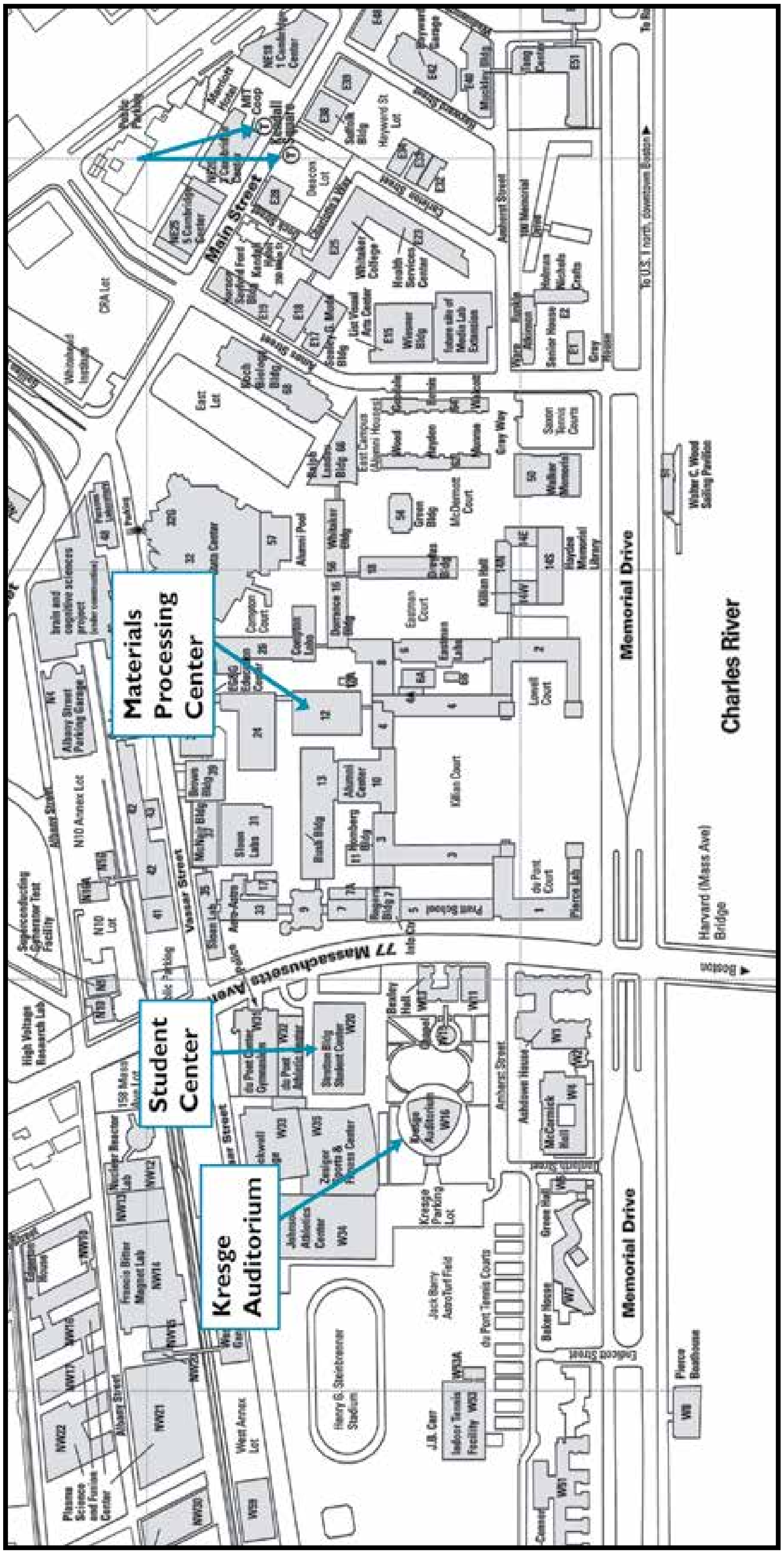
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