CREATING THE NEXT
Materials Innovation Ecosystem
Welcome from the Director

Materials research is foundational in enabling technology advancement in various realms that impact everyday life, ranging from human-computer interfaces and smartphones to automobiles and aircraft, from artificial limbs and organs to batteries and power plants, to name but a few.

The Institute for Materials engages broadly across the Georgia Tech campus with other Interdisciplinary Research Institutes (IRIs) that are focused on broad application domains such as manufacturing, bioengineering and biosciences, and electronics and nanotechnology.

IMat bridges across all colleges and academic units at Georgia Tech, including the Georgia Tech Research Institute to foster a materials innovation ecosystem, designed to support and enhance the collaborative environment of the fast-paced and evolving world of materials research and education.

— David McDowell, Executive Director, Georgia Tech Institute for Materials
MISSION

Formally launched in June 2013, the Georgia Tech Institute for Materials represents a community of more than 200 faculty and staff conducting materials-related research. This community is providing leadership in discovery and development of materials that address 21st century grand challenges in areas such as energy, mobility, infrastructure, computing, communications, security, and health.

IMAT APPROACH

Rather than focusing on short term benefits to be gained by simply supporting faculty in existing research strength areas, IMat has focused on moving GT from one of the nation’s largest materials research universities to one of the best by:

- Consolidating and improving quality of access, support and capabilities of centralized high end materials characterization user facilities
- Embracing 21st century digital materials research through an aggressive strategy of building scientific leadership in materials data science and informatics, rolling this out in the context of various materials core strengths, and
- Fostering incubation of new research directions built on faculty teams by promoting leadership and visioning through workshops, seed funding, and support of cross-cutting large scale proposals.
Our Vision

Discovering new materials and improving our control of the structure and properties of known materials are keys to the continued growth of our economy and our ability to improve life and health for future generations. As consumer demands and competitive requirements drive more complex, higher-efficiency, and enhanced-performance materials solutions, we continue to push the frontiers of the physical limitations of many of the materials in use today.

The Institute for Materials is positioned to amplify the impact of Georgia Tech's research infrastructure through its shared resources and materials innovation initiatives and by bringing value to internal and external stakeholders by:

- Fostering integrative linkages to equipment and shared user resources.
- Supporting cross-cutting, large scale research proposal development.
- Building new modes for networking and e-collaboration in materials research.
- Enhancing collaboration at the seams of core strengths in materials research and grand challenge problems through workshops, team-building, and seed funding.
- Helping to form strategic partnerships with industry, academia, and government aimed at accelerating the pace of materials discovery and development.
- Supporting forward-looking initiatives in interdisciplinary research and education program development.
IMat Shared Resources Overview

Georgia Tech Materials Characterization Facility (MCF)

Unified scheduling and billing infrastructure

Coherent user fees, policies, and training

Strategic relationships with vendors

Materials Characterization Facility Overview

- 10 Expert Staff Members
- ~30000 Usage Hours Per Year
- ~220 Active Billing Groups
- ~700 Active Facility Users
- ~430 New Users Trained
Footprint:
IMat office space (sq ft):
2nd floor PTB, 546
4th floor PTB, ~ 1676

MCF space (sq ft):
Ground floor PTB, 2,459
Marcus bldg., 5,952
Georgia Tech Mechanical Properties Characterization Facility (MPCF)

The MPCF is an interdisciplinary Institute for Materials facility that supports education and research programs related to process-structure-property relations in structural materials. Its principal activities are directed towards the measurement and modeling of the mechanical properties of engineering materials, primarily related to deformation, fatigue and fracture.

Core Equipment & Facilities

- Servohydraulic Test Systems
- Electromechanical Test Systems
- Creep Test Systems
- Drop Weight Impact Tester
- Fretting and Reciprocating Sliding Tester
Georgia Tech’s rolling average annual funding for materials research from 2010-2017 was ~ $80M/yr.

The level of annual funding for Kalidindi and Ramprasad alone is now on par with some of our more highly funded materials core strength areas (e.g., ~$7M/yr). Moreover, this field has cross-cutting character with a multiplier effect on other core strengths.

What does this mean?

- Materials data science is rapidly growing in the broader context (witness # calls that request involvement)
- We have nucleated and grown the activity – perhaps post critical
- Over the past six years, this has been one of the most dynamic growth areas within GT
- Materials domain is well-prepared in current AI @ GT discussions
An unexpected property of nanometer-scale antimony crystals — the spontaneous formation of hollow structures — could help give the next generation of lithium ion batteries higher energy density without reducing battery lifetime. The reversibly hollowing structures could allow lithium ion batteries to hold more energy and therefore provide more power between charges.

Flow of lithium ions into and out of alloy battery anodes has long been a limiting factor in how much energy batteries could hold using conventional materials. Too much ion flow causes anode materials to swell and then shrink during charge-discharge cycles, causing mechanical degradation that shortens battery life. To address that issue, researchers have previously developed hollow “yolk-shell” nanoparticles that accommodate the volume change caused by ion flow, but fabricating them has been complex and costly.

Now, a research team has discovered that particles a thousand times smaller than the width of a human hair spontaneously form hollow structures during the charge-discharge cycle without changing size, allowing more ion flow without damaging the anodes. The research was reported June 1 in the journal Nature Nanotechnology.

“Intentionally engineering hollow nanomaterials has been done for a while now, and it is a promising approach for improving the lifetime and stability of batteries with high energy density,” said Matthew McDowell, assistant professor in the George W. Woodruff School of Mechanical Engineering and the School of Materials Science and Engineering at the Georgia Institute of Technology. “The problem has been that directly synthesizing these hollow nanostructures at the large scales needed for commercial applications is challenging and expensive. Our discovery could offer an easier, streamlined process that could lead to improved performance in a way that is similar to the intentionally engineered hollow structures.”
**Vision:** To be the international leader in defining and enabling the integration of experiments, computation, and data science to address 21st century scientific and technological grand challenges having significant economic and societal impact.

Accelerating materials discovery, design, development, & deployment in “materials + X”

- Advanced consolidated shared user facilities
- Deepening scientific research & accelerating new discovery; use-inspired research

Novel approaches to materials data sciences & informatics

Preparing the future workforce for materials discovery & development
GT PERSPECTIVE | DEFINING THE FUTURE OF MATERIALS INNOVATION

Promote intellectual leadership of cross-cutting GT materials research strengths

- Workshops | Training
- Innovation Lectures | Faculty Panels
- Policy Forums | Advisory Committees

Develop novel value-added programs in future workforce development

- From Learning, Analytics, and Materials to Entrepreneurship and Leadership (FLAMEL) Doctoral Traineeship Program
- AFRL Collaboration Program

Define vision of & pursue value-added S&T:

- Materials data science
- Accelerated discovery & development
- Coupling materials & manufacturing

Couple advanced experimental methods with data science & computation

- Advanced Predictive Computation
- Characterization & Metrology
- Materials database creation & contribution
Five different types of solar cells fabricated by research teams at the Georgia Institute of Technology have arrived at the International Space Station (ISS) to be tested for their power conversion rate and ability to operate in the harsh space environment as part of the MISSE-12 mission. One type of cell, made of low-cost organic materials, has not been extensively tested in space before.

Textured carbon nanotube-based photovoltaic cells designed to capture light from any angle will be evaluated for their ability to efficiently produce power regardless of their orientation toward the sun. Other cells made from perovskite materials and a low-cost copper-zinc-tin-sulfide (CZTS) material – along with a control group of traditional silicon-based cells – will be among the 20 photovoltaic (PV) devices placed on the Materials International Space Station Experiment Flight Facility on the exterior of the ISS for a six-month evaluation. For two of the cells, the launch marked their second trip into space.

“The research questions are the same for all the photovoltaic cells: Can these photo-absorbers be used effectively in space?” said Jud Ready, principal research engineer in the Georgia Tech Research Institute (GTRI), associate director of Georgia Tech’s Center for Space Technology and Research, and deputy director of Georgia Tech’s Institute for Materials. “With this test, we will gain insights into the degradation mechanisms of these materials and be able to compare their power production under varying conditions.”

Organic solar cells developed in the laboratory of Professor Bernard Kippelen at Georgia Tech are processed at low temperatures using solution-based processes over large areas to produce cells with an absorber that can be about 200 times thinner than the width of a human hair.

“With a very low weight and power conversion efficiency values of up to 16%, organic solar cells could yield power values in the hundreds of thousands of watts per kilogram of active material, which is very attractive for space applications,” said Kippelen, the Joseph M. Pettit Professor in the School of Electrical and Computer Engineering. “However, the effects of continuous exposure of these devices in a space environment have not been thoroughly explored. Our interest is in investigating the robustness of the interfaces formed in these devices in a space environment, as well as to improve our understanding of the mechanisms of degradation for organic solar cells in space.”

Traditional flat solar cells are most efficient when the sunlight is directly overhead. Because the direction of the solar flux varies with the orbit, large space vehicles like the ISS use mechanical pointing mechanisms to keep the cells properly aimed.
Those complex mechanisms create maintenance issues, however, and are too heavy for use on very small spacecraft such as CubeSats.

To overcome the pointing problem, Ready’s team developed 3D textured solar cells that can efficiently capture sunlight arriving at different angles. The cells use “towers” made from carbon nanotubes and covered with PV material to trap light that would bounce off standard cells when they are not angled toward the sun.

“With our light-trapping structure, we are agnostic to the sun angle,” said Ready. “Our cells actually work better at glancing angles. On CubeSats, that will allow efficient capture regardless of the orientation of the sun.”

Perovskite cells produced in the laboratory of Zhiqun Lin, professor in the School of Materials Science and Engineering, will also be tested. These materials have known failure mechanisms caused by moisture and oxygen absorption. “These two failure mechanisms won’t be present on the outside of the International Space Station, so this test will allow us to see the performance of these materials without those issues. We should be able to determine whether these known issues might be masking other degradation causes,” Ready said.

CZTS materials are potentially next-generation solar cells made up of low-cost, Earth-abundant materials: copper, zinc, tin and sulfur. The materials have a high absorption coefficient and may be resistant to radiation – useful for space applications – and offer an attractive tradeoff between cost and performance, Ready said.

Silicon-based solar cells produced by the University Center of Excellence in Photovoltaic Research and Education at Georgia Tech will provide a way to compare the performance of the other cells. The laboratory, headed by Regents Professor Ajeet Rohatgi from the School of Electrical and Computer Engineering, provided boron-doped p-type cells with a phosphorus-doped n+ emitter and aluminum-doped p+ back surface field.

These silicon photo-absorber cells will serve as controls to compare the performance of other photo-absorber materials in space,” said Rohatgi.

The 20 PV cells will briefly join three other cells fabricated by Georgia Tech researchers that are already on the ISS. Those three, and two on the newest mission, were part of a 2016 experiment that was unable to record data, though it did provide information about the effects of the space environment on the solar cells.

The Georgia Tech photovoltaic cells were launched to the ISS on Nov. 2 aboard the S.S. Alan Bean, a Northrop Grumman Cygnus spacecraft from NASA’s Wallops Island Facility, as part of a routine resupply mission. For their testing, the cells were integrated into a test package by Alpha Space Test & Research Alliance of Houston.

In addition to those already mentioned, the project also included Canek Fuentes-Hernandez, Matthew Rager, Hunter Chan, Christopher Tran, Christopher Blancher, Zhitao Kang and Conner Awald and Brian Rounsaville, all from Georgia Tech.
Development of new and improved materials is often foundational in solutions to grand challenges that affect quality of life such as mobile communications and computing, sustainable energy, water and food supplies, mobility, health, and security. Today’s competitive environment demands that various aspects of materials discovery, design, and development be pursued concurrently.

Some of these disciplines have been taught for decades in the context of the materials sciences, such as structure characterization, materials theory and computation, databases, and property measurements. This innovation ecosystem further expands into fields such as uncertainty quantification and management, manufacturing processes, entrepreneurship, multiscale modeling, knowledge systems and databases, systems design exploration, manufacturing scale-up, automation, in situ process measurements, and materials data sciences and informatics.

**IMat Skills Development Courses and Workshops 2019**

- Materials Informatics 101: Data Science Literacy
- Atom Probe Tomography for Atomic Scale Characterization and Biomaterials Analysis
- Technical Webinar: In-situ heating experiments in TEM/STEM
- X-Ray Diffraction (XRD) for the Analysis of Thin Films
- Advances in EELS Instrumentation and Analysis: High-Speed Spectroscopy, with Extended Energy and Dynamic Range
- Quantitative Analysis of X-Ray Powder Diffraction Data using HighScore Plus
- Workshop on Synchrotron X-ray Analytical Methods: XAS and XES
IMat Sandia Academic Alliance

IMat Undergrads Attend Remote Research Experience

Sandia’s Center for Integrated Nanotechnologies (CINT) and GT’s Institute of Materials (IMat) collaborated on the jointly funded CINT talent initiative with the intent of engaging eight undergraduate students to do research with CINT users in the summer of 2020. Jud Ready, Deputy Director, Innovation Initiatives for IMat, Jeff Nelson, Senior Manager for CINT, Remi Dingreville, Sandia Nanostructure Physics staff member and adjunct professor at GT, and Rebecca Horton, Partnerships Manager, have all engaged in this effort.

IMat Faculty Attend RAD Mission Workshop at Sandia

In January of 2020, Sandia hosted 12 GT’s IMAT faculty members for a two-day workshop that fostered many networking opportunities in the areas of materials, nanotechnologies, and the Resilient Agile Deterrence Mission Campaign at Sandia. Discussions also included an undergraduate internship pilot with CINT scientists, a joint investment between GT and Sandia. Georgia Tech’s Olof Westerstahl who is Sandia’s liaison for new research engagements, also attended workshop and met with additional Sandians outside of the workshop.
A team of researchers from the Georgia Institute of Technology and The Ohio State University has developed a soft polymer material, called magnetic shape memory polymer, that uses magnetic fields to transform into a variety of shapes. The material could enable a range of new applications from antennas that change frequencies on the fly to gripper arms for delicate or heavy objects.

The material is a mixture of three different ingredients, all with unique characteristics: two types of magnetic particles, one for inductive heat and one with strong magnetic attraction, and shape-memory polymers to help lock various shape changes into place.

“This is the first material that combines the strengths of all of these individual components into a single system capable of rapid and reprogrammable shape changes that are lockable and reversible,” said Jerry Qi, a professor in the George W. Woodruff School of Mechanical Engineering at Georgia Tech.

The research, which was reported Dec. 9 in the journal Advanced Materials, was sponsored by the National Foundation of Science, the Air Force Office of Scientific Research, and the Department of Energy.

To make the material, the researchers began by distributing particles of neodymium iron boron (NdFeB) and iron oxide into a mixture of shape memory polymers. Once the particles were fully incorporated, the researchers then molded that mixture into various objects designed to evaluate how the material performed in a series of applications.
For example, the team made a gripper claw from a t-shaped mold of the magnetic shape memory polymer mixture. Applying a high-frequency, oscillating magnetic field to the object caused the iron oxide particles to heat up through induction and warm the entire gripper. That temperature rise, in turn, caused the shape memory polymer matrix to soften and become pliable. A second magnetic field was then applied to the gripper, causing its claws to open and close. Once the shape memory polymers cool back down, they remain locked in that position.

The shape-changing process takes only a few seconds from start to finish, and the strength of the material at its locked state allowed the gripper to lift objects up to 1,000 times its own weight.

“We envision this material being useful for situations where a robotic arm would need to lift a very delicate object without damaging it, such as in the food industry or for chemical or biomedical applications,” Qi said.

The new material builds on earlier research that outlined actuation mechanisms for soft robotics and active materials and evaluated the limitations in current technologies.

“The degree of freedom is limited in conventional robotics” said Ruike (Renee) Zhao, an assistant professor in the Department of Mechanical and Aerospace Engineering at Ohio State. “With soft materials, that degree of freedom is unlimited.”

The researchers also tested other applications, where coil-shaped objects made from the new material expanded and retracted – simulating how an antenna could potentially change frequencies when actuated by the magnetic fields.

“This process requires us to use of magnetic fields only during the actuation phase,” Zhao said. “So, once an object has reached its new shape, it can be locked there without constantly consuming energy.”

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For more information about the Georgia Tech Institute for Materials, please contact info@imat.gatech.edu or call 404.894.7769.