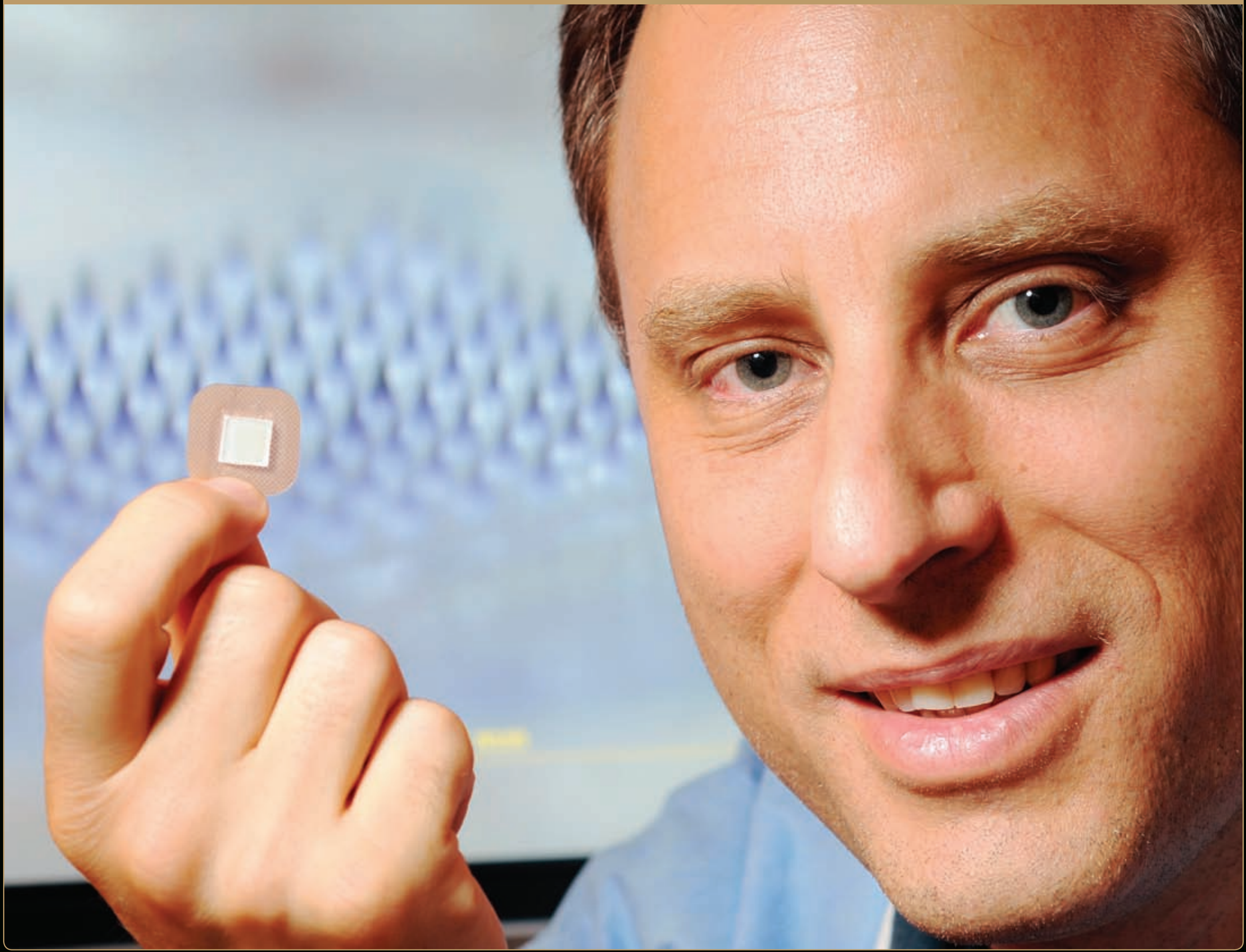
Research Horizons

A Publication of the Georgia Institute of Technology *Summer/Fall 2011*

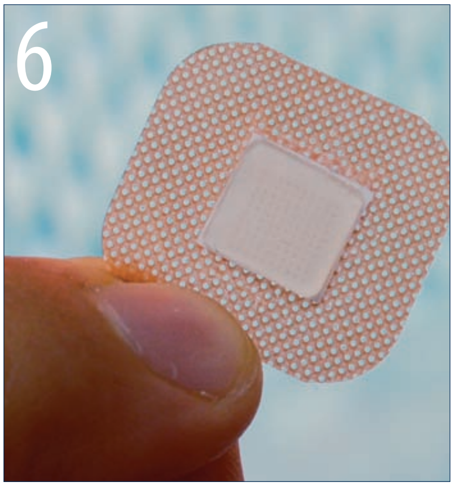
DEVELOPING INNOVATIVE MEDICAL DEVICES



Georgia Institute of Technology

- *Power from the Air*
- *Taking the Heat*
- *Robotic Mapping*
- *Coal-Fired Fuel Cells*
- *Blight to Beauty*

GTRESEARCHNEWS.GATECH.EDU



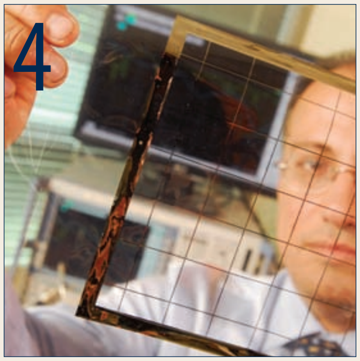
"One of Georgia Tech's major research strengths is its ability to bring engineering together with the biosciences to create new solutions for health care problems. Georgia Tech has a history of bringing innovations from the laboratory through the functional prototype stage, while coordinating the other commercialization activities necessary to bring them to market."

– Stephen E. Cross, executive vice president for research

COVER STORY

"There is a large amount of electromagnetic energy all around us, but nobody has been able to tap into it. We are using an ultra-wideband antenna that lets us exploit a variety of signals in different frequency ranges, giving us greatly increased power-gathering capability."

– Manos Tentzeris, professor in the School of Electrical and Computer Engineering



"When first responders – whether it's a firefighter in downtown Atlanta or a soldier overseas – confront an unfamiliar structure, it's very stressful and potentially dangerous because they have limited knowledge of what they're dealing with. If those first responders could send in robots that would quickly search the structure and send back a map, they'd have a much better sense of what to expect and they'd feel more confident."

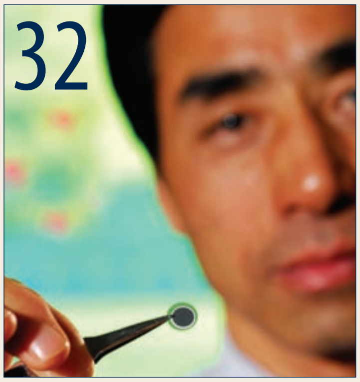
– Henrik Christensen, professor in the College of Computing

"There is still a lot to be learned about how black holes get fueled and how some accrete slowly while others grow rapidly. The astrophysics of black holes is actually very important in determining what our universe looks like."

– David Ballantyne, assistant professor in the School of Physics

“This could ultimately be the cleanest, most efficient and cost-effective way of converting coal into electricity. And by providing an exhaust stream of pure carbon dioxide, this technique could also facilitate carbon sequestration without the separation and purification steps now required for conventional coal-burning power plants.”

– Meilin Liu, Regents professor in the School of Materials Science and Engineering



“Without changing the composition of the underlying silicon-germanium transistors, we leveraged SiGe’s natural merits to develop new circuit designs, as well as new approaches to packaging the final circuits, to produce an electronic system that could reliably withstand the extreme conditions of space.”

– John Cressler, professor in the School of Electrical and Computer Engineering

“Converting this underused commercial real estate to green space that could be built on again when the economy improves would be transformational. The conversion would create demolition, design and landscaping jobs, and stabilize housing and property values, around the distressed properties.”

– Kevin Caravati, senior research scientist at the Georgia Tech Research Institute

Georgia Tech *Research Horizons* Magazine

Georgia Tech *Research Horizons* magazine is published three times per year to communicate the results of research conducted at the Georgia Institute of Technology. The magazine is published by the Research News & Publications Office, and supported by the Executive Vice President for Research and the Georgia Tech Research Institute.

Articles and photographs may be reprinted with credit to “Georgia Tech Research Horizons Magazine.”

Digital versions of this magazine, along with downloadable PDFs, can be found on the Research News website: (gtresearchnews.gatech.edu). The site is searchable, and issues back to 1995 are available.

© 2011 by the Georgia Tech Research Corporation. All rights reserved. ISSN #1060-669

CONTENTS

COVER STORY

6 Developing Innovative Medical Devices

FEATURES

4 Air Power
22 Taking the Heat
24 Team Robot
28 Proving Darwin Right
30 Active Galactic Nuclei
32 Self-Cleaning Anodes
34 Silicon Germanium in Space
38 Blight to Beauty
40 Making Reading Better

DEPARTMENTS

26 Research in the News
27 Awards and Honors
42 Research Notes

ADDRESS CORRECTIONS/REPRINTS
Please send address corrections and requests for additional subscriptions to John Toon (jtoon@gatech.edu) or 404.894.6986.

POSTMASTER
Send address changes to: Research News & Publications Office
Georgia Institute of Technology
75 Fifth St., N.W., Suite 100
Atlanta, GA 30308-1021 USA

STAFF
Editor: John Toon
Writers: Abby Robinson, Rick Robinson, John Toon
Photography: Gary Meek, Rob Felt
Proofreading: Lincoln Bates, Sarah Goodwin
Design: Inward Solutions
Printing: Graphic Solutions, Inc.

Keep up with Georgia Tech Research News:
Twitter: @gtresearchnews
Facebook: www.facebook.com/gtresearchnews

Cover: Patches containing hundreds of tiny microneedles could one day replace conventional hypodermic needles for drug and vaccine delivery. Here, Regents professor Mark Prausnitz holds a prototype microneedle patch. (Photo: Gary Meek)

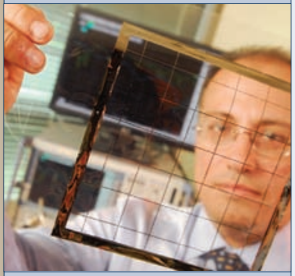
Electromagnetic energy from such sources as radio and TV transmitters is all around us, and researchers have discovered a way to capture and harness that ambient energy to power networks of wireless sensors, microprocessors and communications chips. The researchers are using inkjet printers to combine sensors, antennas and energy-scavenging capabilities on paper or flexible polymers.

Air Power:

New Device Captures Ambient Electromagnetic Energy to Drive Small Electronic Devices

By Rick Robinson

Photo: Gary Meek



Manos Tentzeris, a professor in the School of Electrical and Computer Engineering, displays an inkjet-printed rectifying antenna used to convert microwave energy to DC power. This grid was printed on flexible Kapton material and is expected to operate with frequencies as high as 10 gigahertz.

Researchers have discovered a way to capture and harness energy transmitted by such sources as radio and television transmitters, cell phone networks and satellite communications systems. By scavenging this ambient energy from the air around us, the technique could provide a new way to power networks of wireless sensors, microprocessors and communications chips.

"There is a large amount of electromagnetic energy all around us, but nobody has been able to tap into it," said Manos Tentzeris, a professor in the Georgia Tech School of Electrical and Computer Engineering. "We are using an ultra-wideband antenna that lets us exploit a variety of signals in different frequency ranges, giving us greatly increased power-gathering capability."

Tentzeris and his team are using inkjet printers to combine sensors, antennas and energy-scavenging capabilities on paper or flexible polymers. The resulting self-powered wireless sensors could be used for chemical, biological, heat and stress sensing for defense and industry; radio-frequency identification (RFID) tagging for manufacturing and shipping; and monitoring tasks in many fields including communications and power usage.

A presentation on this energy-scavenging technology was given July 6, 2011, at the IEEE Antennas and Propagation Symposium in Spokane, Wash. The discovery is based on research supported by multiple sponsors, including the National Science Foundation, the Federal Highway Administration and Japan's New Energy and Industrial Technology Development Organization (NEDO).

Communications devices transmit energy in many different frequency ranges, or bands. The team's scavenging devices can capture this energy, convert it from AC to DC, and then store it in capacitors and batteries. The scavenging technology can now take advantage of frequencies from FM radio to radar, a range spanning 100 megahertz (MHz) to 15 gigahertz (GHz) or higher.

Scavenging experiments utilizing TV bands have already yielded power amounting to hundreds of microwatts, and multi-band systems are expected to generate one milliwatt or more. That amount of power is enough to operate many small electronic devices, including a variety of sensors and microprocessors.

And by combining energy-scavenging technology with supercapacitors and cycled operation, the Georgia Tech team expects to power devices requiring above 50 milliwatts. In this approach, energy builds up in a battery-like supercapacitor and is utilized when the required power level is reached, said Rushi Vyas, a Ph.D. candidate who has used this technique to power-on microprocessors using solar and wireless scavengers.

The researchers have successfully operated a temperature sensor using electromagnetic energy captured from a TV station that was four miles away in midtown Atlanta. They are preparing another demonstration in which an embedded microprocessor would be activated simply by holding it in the air.

Exploiting a range of electromagnetic bands increases the dependability of energy-scavenging devices, explained Tentzeris, who is also a faculty researcher in the Georgia Electronic Design Center at Georgia Tech. If one frequency range fades temporarily due to usage variations, the system can still exploit other frequencies.

A scavenging device could be used by itself or in tandem with other generating technologies. For example, scavenged energy could help a solar element charge a battery during the day. At night, when solar cells don't provide power, scavenged energy would continue to increase the battery charge or would prevent discharging.

The researchers are utilizing inkjet technology to print these energy scavenging devices on paper or flexible paper-like polymers – a technique they already are using to produce sensors and antennas. The result would be paper-based wireless sensors that are self-powered, inexpensive and able to function independently almost anywhere.

To print electrical components and circuits, the Georgia Tech researchers use a standard materials inkjet printer. However, they add silver nanoparticles and/or other nanoparticles in an emulsion. This approach enables the team to print not only RF components and circuits, but also novel sensing devices based on such nanomaterials as carbon nanotubes.

When Tentzeris and his research group began inkjet printing of antennas in 2006, the paper-based circuits only functioned at frequencies of 100 or 200 MHz, recalled Vyas, who is working with Tentzeris and Ph.D. candidate Vasileios Lakafosis on several projects, including inkjet printing with solar, wireless and scavengers powered by human motion.

"We can now print circuits that are capable of functioning at up to 15 GHz and up to 60 GHz if we print on a polymer," Vyas said. "So, we have seen a frequency operation improvement of two orders of magnitude."

The researchers believe that self-powered, wireless paper-based sensors will soon be widely available at very low cost. The resulting proliferation of autonomous, inexpensive sensors could be used for monitoring applications in airport security, energy conservation, structural integrity, food and perishable items, and health care. rh

CONTACT

Manos Tentzeris
emmanouil.tentzeris@ece.gatech.edu

"There is a large amount of electromagnetic energy all around us, but nobody has been able to tap into it. We are using an ultra-wideband antenna that lets us exploit a variety of signals in different frequency ranges, giving us greatly increased power-gathering capability."

— Manos Tentzeris, professor in the School of Electrical and Computer Engineering

Rushi Vyas (front) holds a prototype energy-scavenging device, while School of Electrical and Computer Engineering professor Manos Tentzeris displays a miniaturized flexible antenna that was inkjet-printed on paper and could be used for broadband energy scavenging.

Photo: Gary Meek

By harnessing its engineering, scientific and computing capabilities and its entrepreneurial tradition, as well as the Atlanta medical community, Georgia Tech is advancing the field of medical device design and bringing new devices to market. Beyond the health benefits, these medical devices also have an economic development impact.

Medical Device Innovation:

Georgia Tech Develops Technologies to Solve Health Care Problems

By Abby Robinson

Photo: Rob Felt

Biomedical engineering professor Charlie Kemp accepts a towel from EL-E, a robot designed to help people with limited mobility perform everyday tasks. The robot is guided by a green laser pointer.

After peeling off the protective film from one side, the patch – which is about the size of a postage stamp – is pressed onto the forearm of a young child. Hundreds of tiny microneedles located on the surface of the patch painlessly enter the upper layers of the child's skin, where they quickly dissolve. Made of a medical polymer, the needles carry vaccine particles directly to the specialized cells used by the skin to battle invading microbes.

This is one scenario that Georgia Tech researchers envision for using the microneedle-based vaccine patch they are developing with immunology experts at Emory University. The patch, which could be available within five years, might be administered by persons without medical training, providing a simple way to rapidly immunize large populations during pandemics.

Microneedles are just one example of the medical devices under development at Georgia Tech, often in collaboration with institutions such as Emory. By harnessing its engineering, scientific and computing capabilities and its entrepreneurial tradition, as well as the Atlanta medical community, Georgia Tech is advancing the field of medical device design and bringing new devices to market.

"One of Georgia Tech's major research strengths is its ability to bring engineering together with the biosciences to create new solutions for health care problems," said Stephen E. Cross, executive vice president for research at Georgia Tech. "Georgia Tech has a history of bringing innovations from the laboratory through the functional prototype stage, while coordinating the other commercialization activities necessary to bring them to market."

Beyond the health benefits, these medical devices also have an economic development benefit. Displaying more robust vital signs than most business sectors, the global medical device market could top $300 billion this year, according to industry estimates. Research institutions like Georgia Tech have played a critical role in this growth by developing technologies that are ultimately licensed to medical device firms or that form the basis for startup companies that commercialize them for clinical use.

The roster of Atlanta-based startup companies that have built new medical devices based on technology developed at Georgia Tech includes CardioMEMS, MedShape Solutions and Zenda Technologies. The Global Center for Medical Innovation (GCMI), a new medical device development center under construction in midtown Atlanta, promises to expand this roster, while assisting both established and early-stage companies. And startup assistance is available from the VentureLab unit in Georgia Tech's Enterprise Innovation Institute and from the Georgia Research Alliance's commercialization program.

Depending on the type and complexity of the medical device, the process of moving technology innovations from the research laboratory to the bedside can take years. Prototypes must be designed and improved upon, preliminary laboratory and animal tests must be conducted, and the safety and efficacy of many new medical devices must be tested in clinical trials. Most devices also require federal regulatory ap-

This portable screening device called DETECT makes quick neuropsychological assessments to identify mild cognitive impairment, which could indicate the early stages of Alzheimer's disease.

Photo: Rob Felt

CONTACTS

Gang Bao
gang.bao@bme.gatech.edu

Charlene Bayer
charlene.bayer@gtri.gatech.edu

Pamela Bhatti
pamela.bhatti@ece.gatech.edu

Kristin Bing
kristin.bing@gtri.gatech.edu

Levent Degertekin
levent.degertekin@me.gatech.edu

Robert Delano
robert.delano@gtri.gatech.edu

Ellen Yi-Luen Do
ellendo@gatech.edu

Brad Fain
brain.fain@gtri.gatech.edu

Craig Forest
cforest@gatech.edu

Maysam Ghovanloo
mgh@gatech.edu

Paul Hasler
paul.hasler@ece.gatech.edu

Wayne Hodges
hwhodges@devices.net

Manpreet Hora
manpreet.hora@mgt.gatech.edu

Charlie Kemp
charlie.kemp@bme.gatech.edu

David Ku
david.ku@me.gatech.edu

Wilbur Lam
wilbur.lam@emory.edu

Michelle LaPlaca
michelle.laplaca@bme.gatech.edu

John McDonald
john.mcdonald@biology.gatech.edu

Shuming Nie
snie@emory.edu

Mark Prausnitz
mark.prausnitz@chbe.gatech.edu

Minoru Shinohara
shinohara@gatech.edu

Stephen Sprigle
stephen.sprigle@coa.gatech.edu

Thad Starner
thad@gatech.edu

Jun Ueda
jun.ueda@me.gatech.edu

Bruce Walker
bruce.walker@psych.gatech.edu

May Wang
maywang@bme.gatech.edu

Ajit Yoganathan
ajit.yoganathan@bme.gatech.edu

Photo: Gary Meek

Ellen Yi-Luen Do, an associate professor with a joint appointment in the School of Architecture and School of Interactive Computing, helps Sister Margaret Mary Bauch use the ClockReader software that Do developed.

proval before they can be introduced into the marketplace.

This article examines various health care technologies developed at Georgia Tech that are in different stages of research, development and commercialization. The article includes devices designed for condition detection and diagnosis, monitoring and treatment, surgery, drug delivery, and rehabilitation and mobility assistance.

Devices Designed to Detect and Diagnose Clinical Conditions

Advancing the Detection of Neurological Conditions

Tests capable of detecting early Alzheimer's disease are typically taken with a pen and paper and last about an hour and a half. Because of their length and expense, the tests are not used as regular screening tools.

Researchers at Georgia Tech and Emory University have developed a portable screening device called DETECT that makes quick neuropsychological assessments to identify mild cognitive impairment, which could indicate the early stages of Alzheimer's disease. The device runs patients through a 10-minute battery of visual stimuli that requires simple responses, assessing cognitive abilities such as reaction time and memory capabilities.

Results of a 400-person clinical study conducted at Emory's Wesley Woods Center demonstrated that the DETECT test had accuracy similar to that of the pen-and-paper test.

"We envision the DETECT test could be part of normal preventative care an individual receives from a general practitioner, like a prostate-specific antigen test or mammogram, serving as a cognitive-impairment vital sign of sorts that can be tracked from year to year," said Michelle LaPlaca, an associate professor in the Wallace H. Coulter Department of Biomedical Engineering at Georgia Tech and Emory University.

LaPlaca and device co-creator David Wright, an assistant professor of emergency medicine at Emory, founded a startup company called Zenda Technologies to commercialize the technology, which is currently being used in doctors' offices in Georgia and Alabama. DETECT also has potential for use in assessing concussion and mild traumatic brain injury.

For another project, researchers are focusing on one of the pencil-and-paper tests neurologists administer to quickly screen for signs of cognitive dysfunction: the clock-drawing test. For example, an individual being assessed is asked to draw numbers on a circle so that it looks like a clock, with hands pointing to "10 minutes after 11."

To automate and standardize the administration and evaluation of the clock-drawing task, Georgia Tech researchers have designed a software program called ClockReader that allows users to complete the test on a tablet computer with a stylus pen. The software provides spatial, temporal and geometric sketch information, along with behavior data, including time required to complete the task and pressure of the pen. Physicians can also watch a video of how an individual drew the clock.

"Our software program has the potential to reduce the amount of time required to analyze the results of the clock-drawing test, which would hopefully promote more frequent administration to measure variation over time," said Ellen Yi-Luen Do, an associate professor with a joint appointment in the School of Architecture and School of Interactive Computing at Georgia Tech.

In collaboration with Allan Levey, director of the Alzheimer's Disease Research Center at Emory University, more than 30 individuals with an average age of 75 tested the usability of the software. While most of the participants reported limited or no computer experience, their drawings using a stylus were almost identical to their drawings with a pencil and paper. The researchers are currently testing the software's value to physicians.

This project is supported by the National Science Foundation, Korean Institute for the Advancement of Technology, Atlanta Clinical & Translational Science Institute, Health Systems Institute, and the Alzheimer's Disease Research Center at Emory.

Neuropsychological exams are also sometimes given to individuals who have suffered a concussion. Because walking and thinking at the same time can be especially difficult for these individuals, scientists hope to use that multitasking challenge – measured by a simple radar system – to quickly screen individuals who may have suffered brain injuries.

By asking an individual to walk a short distance while saying the months of the year in reverse order, researchers at the Georgia Tech Research Institute (GTRI) are trying to determine if that person is impaired. This simple test, which could be performed on the sideline of a sporting event or on a battlefield, has the potential to help coaches and commanders decide whether athletes and soldiers are ready to engage in activity again.

"Research performed at the University of Oregon found that when a person with a concussion performs cognitive and motor skill tasks simultaneously, they have a different gait pattern than a healthy individual, and we are working to identify those anomalies in a person's walk with a radar system similar to those used by police for measuring the speed of vehicles," said GTRI research engineer Jennifer Palmer.

The researchers have successfully used this method to distinguish the gait patterns of healthy individuals wearing calibrated vision-impairment goggles – which have been shown by research to potentially simulate the visual impairment one might experience with a concussion – from the patterns collected when the individuals did not wear the goggles. GTRI research engineers Kristin Bing and Amy Sharma, principal research scientist (ret.) Eugene Greneker and research scientist Teresa Selee are also working on this project.

Simplifying the Detection of Cancer and Pneumonia

Another GTRI researcher, Charlene Bayer, is developing a portable breathalyzer to detect the presence of breast cancer. Bayer, a GTRI principal research scientist, designed and tested the device in collaboration with Brani Vidakovic, a professor in the Wallace H. Coulter Department of Biomedical Engineering at Georgia Tech and Emory University; Sheryl G.A. Gabram, a professor of surgery in the Division of Surgical Oncology at Emory University; and University of Ulm professor Boris Mizaikoff.

When an individual exhales into the device, compounds in the breath are trapped for further examination. The sensing methodology combines gas chromatography – a technique for separating complex compounds – with mass spectrometry, which identifies the chemical makeup of a substance. Specific patterns in the compounds are then found and used to confirm the presence or absence of the disease.

The research team conducted a clinical study analyzing more than 300 volatile organic compounds in breath samples of 20 healthy women over the age of 40, and 20 women recently diagnosed with stage II-IV breast cancer who had not yet received treatment. The results showed that the breath analysis was able to determine whether the sample came from a cancer patient or healthy subject 78 percent of the time.

Bayer recently completed a pilot study on individuals diagnosed with lung cancer, in collaboration with Suresh Ramalingam, an associate professor in the Department of Hematology and Medical Oncology at Emory University.

Also utilizing the exhalation of breath, a device called PneumoniaCheck could help identify the pathogens responsible for an individual's pneumonia. After an individual coughs deeply into the device, the apparatus segregates contents from the upper and lower airways without complicated valves, buttons or active user control. The aerosol specimens captured from the lower lung can then be

Photo: Rob Felt

Renovation Begins on Medical Device Innovation Center

U.S. Assistant Secretary of Commerce for Economic Development John Fernandez (left) learns about startup company CardioScout from Dr. James Fonger of Saint Joseph's Translational Research Institute. Fernandez visited the Global Center for Medical Innovation during a visit to Atlanta in August 2011.

A "wall-breaking" ceremony held August 2, 2011, marked the start of building renovations for the Southeast's first comprehensive medical device innovation center. The Global Center for Medical Innovation (GCMI) has been awarded $3.6 million from the U.S. Economic Development Administration and the Georgia Research Alliance (GRA) to support development of the initiative.

The money will be used to build and equip a prototyping design and development facility that will accelerate the commercialization of next-generation medical devices and technology. The funding will also support establishment of innovative approaches for commercializing medical devices developed in universities, hospitals, companies and other organizations.

GCMI will be housed in a 12,000-square-foot facility being renovated in midtown Atlanta near the Georgia Tech campus. The facility, expected to open by the end of 2011, will house design, material and mechanical engineering resources, along with state-of-the-art rapid and functional prototyping equipment capable of producing a wide range of medical devices for development, pre-clinical testing and clinical studies.

"Investments in Georgia's research universities are helping to create the knowledge and innovation necessary to expand the medical device industry in the state," said Mike Cassidy, president and CEO of the GRA, a public-private organization that supports the development of technology industry in Georgia. "Through activities like GCMI and Georgia Research Alliance commercialization activities at the state's research universities, we are supporting the development and growth of this promising industry."

GCMI currently has four member organizations: the Georgia Institute of Technology, Piedmont Hospital, Saint Joseph's Translational Research Institute/Saint Joseph's Hospital and the GRA – a 501(c)3 organization. The new center grew out of a decade or more of experience commercializing discoveries from laboratories at partner institutions.

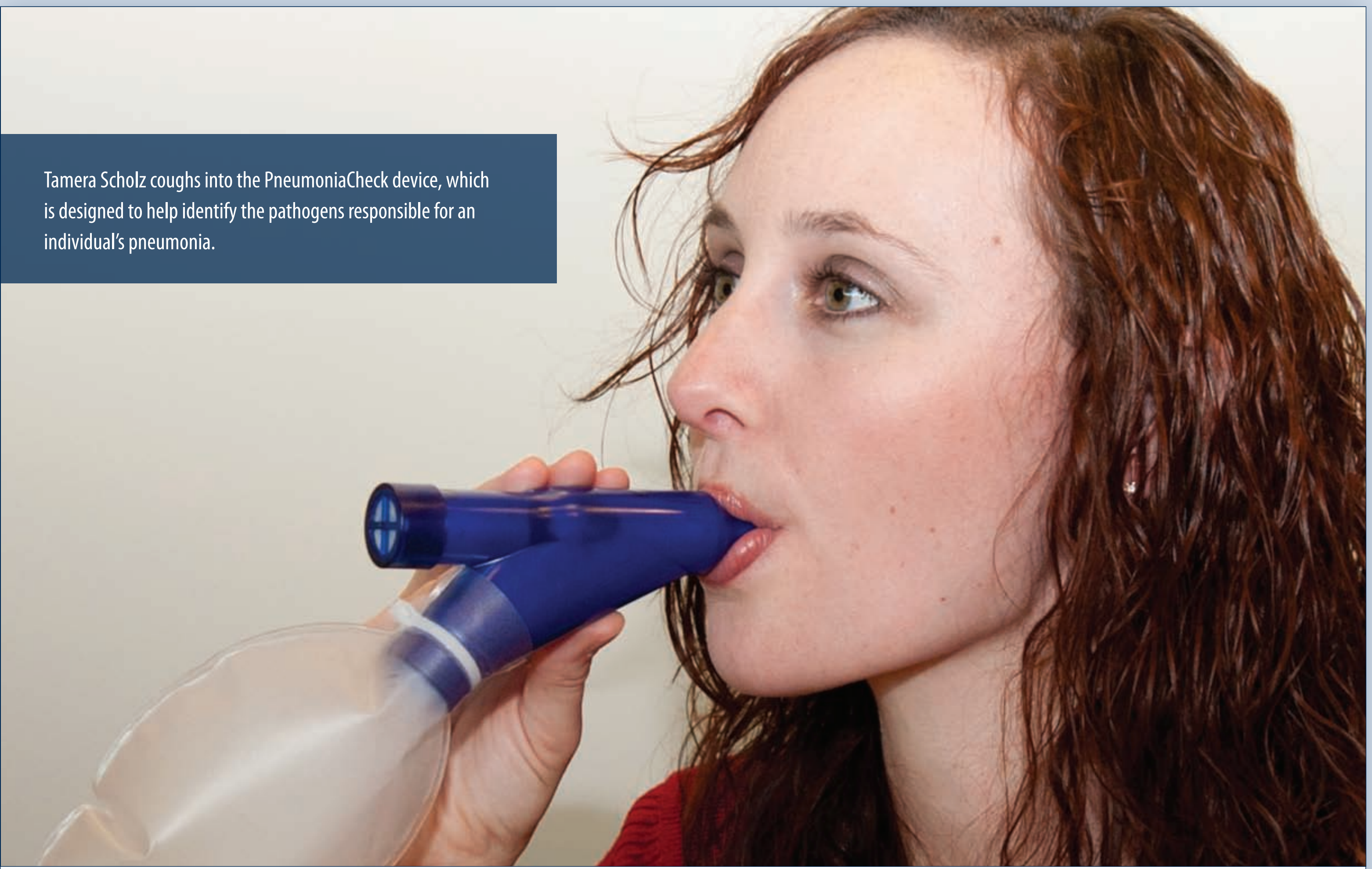
GCMI

"For many years we have seen the need for a prototyping center that would provide medical device innovators with the support they need to quickly bring new innovations to market," said Wayne Hodges, executive director of the center. "Our new facility will allow intellectual property developed in Atlanta, Georgia and the Southeast to remain here and provide long-term benefit as these innovations move into new products and new companies."

— John Toon

(More information on GCMI: www.devices.net)

Photo: Jennifer Tyner



Tamera Scholz coughs into the PneumoniaCheck device, which is designed to help identify the pathogens responsible for an individual's pneumonia.

analyzed using commercial genomic DNA methods to determine the pathogen that should be treated.

"Identifying the pathogens that cause pneumonia can be challenging because a high-quality specimen from the lower lung is difficult to obtain. PneumoniaCheck contains a filter to collect the aerosolized pathogens and excludes oral contaminants from the sample to improve specimen quality," said David Ku, a Regents professor in the Woodruff School of Mechanical Engineering at Georgia Tech. Ku is also the Lawrence P. Huang Chair Professor for Engineering Entrepreneurship in the Georgia Tech College of Management and professor of surgery at Emory University.

PneumoniaCheck has been approved by the U.S. Food and Drug Administration. The device was designed by Ku, Georgia Tech graduate students Tamera Scholz and Prem Midha, and Larry Anderson, who worked at the U.S. Centers for Disease Control and Prevention while this research was conducted. Results of verification testing of the device were published in the December 2010 issue of *Journal of Medical Devices*.

Facilitating Diagnoses of Heart Disease and Ear Infections

Levent Degertekin is designing tiny devices micromachined from silicon that may make diagnosing and treating coronary artery diseases easier.

Degertekin, the George W. Woodruff Chair in Mechanical Systems, and Paul Hasler, a professor in the School of Electrical and Computer Engineering at Georgia Tech, micromachined intravascular ultrasound imaging arrays with integrated electronics. The devices can be inserted into one-millimeter-diameter catheters to image the arteries of the heart in three dimensions at high resolution using high-frequency ultrasound waves.

"The ability to integrate electronics on the same silicon chip is key for successful implementation of cost-effective, flexible catheter-based imaging arrays to reduce the number of cables and electronic interference noise," said Degertekin. "Current piezoelectric transducer materials cannot be manufactured with the precision to implement these arrays."

The system boasts a more compact design and three-dimensional imaging capability for guiding cardiologists during interventions, such as those for completely blocked arteries. The technology also offers higher resolution than current intravascular ultrasound systems, which help diagnose vulnerable plaque, a leading cause of heart attacks.

Funding for this research currently is provided by the National Institutes of Health. To commercialize the technology, the researchers have formed a startup company called SIBUS Medical, which is receiving assistance from VentureLab, a unit of Georgia Tech's Enterprise Innovation Institute that nurtures faculty startup companies.

Another device that may be commercialized in the future is the RemOtoscope – a smartphone attachment designed for at-home ear examinations. Ear infections result in more than 15 million doctor office visits each year in the United States because diagnosing them requires direct observation of the child's eardrum and ear canal with a device called an otoscope.

Wilbur Lam, an assistant professor with a joint appointment in the Wallace H. Coulter Department of Biomedical Engineering at Georgia Tech and Emory University and the Department of Pediatrics at Emory University, envisions a physician remotely guiding placement of the device and diagnosing the condition via real-time video consultation with parents at home. Diagnosing ear infections at home could result in significant savings to the health care system.

The RemOtoscope attachment includes an illumination system that uses the smartphone's flash as the light source, an optical system to provide magnification, and a software application to record data to the phone. With funding from the Atlanta Clinical & Translational Science Institute, Lam plans to solicit physician feedback, improve the device based on that feedback, and conduct a double-blind study assessing the diagnostic image quality of the device.

"Once we collect clinical data and quantify the diagnostic efficacy of the RemOtoscope as it compares to a conventional otoscope, we may be able to begin changing how ear infections are diagnosed and treated," added Lam.

Devices Designed to Treat and Monitor Clinical Conditions

Designing Systems to Treat Ovarian Cancer and Pediatric Kidney Disease

There is no FDA-approved continuous bedside dialysis device for children. When critically ill children need kidney dialysis, doctors are forced to adapt adult-size dialysis equipment. These adapted adult devices can withdraw too much fluid from a pediatric patient, leading to dehydration, shock and loss of blood pressure.

To address this problem, which affects at least 4,000 children in the United States per year, doctors and engineers teamed up to develop a kidney replacement device designed especially for children. The prototype device is much smaller than existing dialysis equipment and works in tandem with equipment that supplements the function of the heart and lungs for severely ill patients.

"We have built a robust device that achieves automated and accurate fluid management," said Ajit Yoganathan, a Georgia Tech Regents professor and the Wallace H. Coulter Distinguished Faculty Chair in Biomedical Engineering.

With funding from the National Institutes of Health, Yoganathan and Arvind Santhanakrishnan, a postdoctoral fellow in the Coulter Department, worked with Matthew Paden, an assistant professor of pediatric critical care at Emory and a physician at Children's Healthcare of Atlanta, to design the device. The team is currently testing the prototype's biological compatibility and hopes to be ready for *in vivo* studies later this year and clinical trials in five years.

John McDonald, a professor in Georgia Tech's School of Biology and chief research scientist of Atlanta's Ovarian Cancer Institute, and research scientist Ken Scarberry are designing a similar system that would treat ovarian cancer. Comparable in principle to kidney dialysis equipment, the system would circulate a buffer solution through the peritoneal cavity to pick up free-floating cancer cells that have broken off the primary tumor. The device is the basis for a startup company called Sub-Micro.

Added to fluids removed from the abdomen, magnetic nanoparticles engineered to capture cancer cells would latch onto the free-floating cancer cells, allowing both the nanoparticles and cancer cells to be removed by magnetic filters before the fluids are returned to the body. In mice injected with ovarian cancer cells, a single treatment with an early prototype of the system captured enough of the cancer cells that the treated mice lived nearly one-third longer than untreated ones.

The research, which was published in the January 2011 issue of the journal *Nanomedicine*, has been supported by the Georgia Research Alliance, the Ovarian Cancer Institute, the Robinson Family Foundation and the Deborah Nash Harris Endowment. Sub-Micro also has raised private funding to support its prototype development and is receiving assistance from VentureLab, a unit of Georgia Tech's Enterprise Innovation Institute that nurtures faculty startup companies.

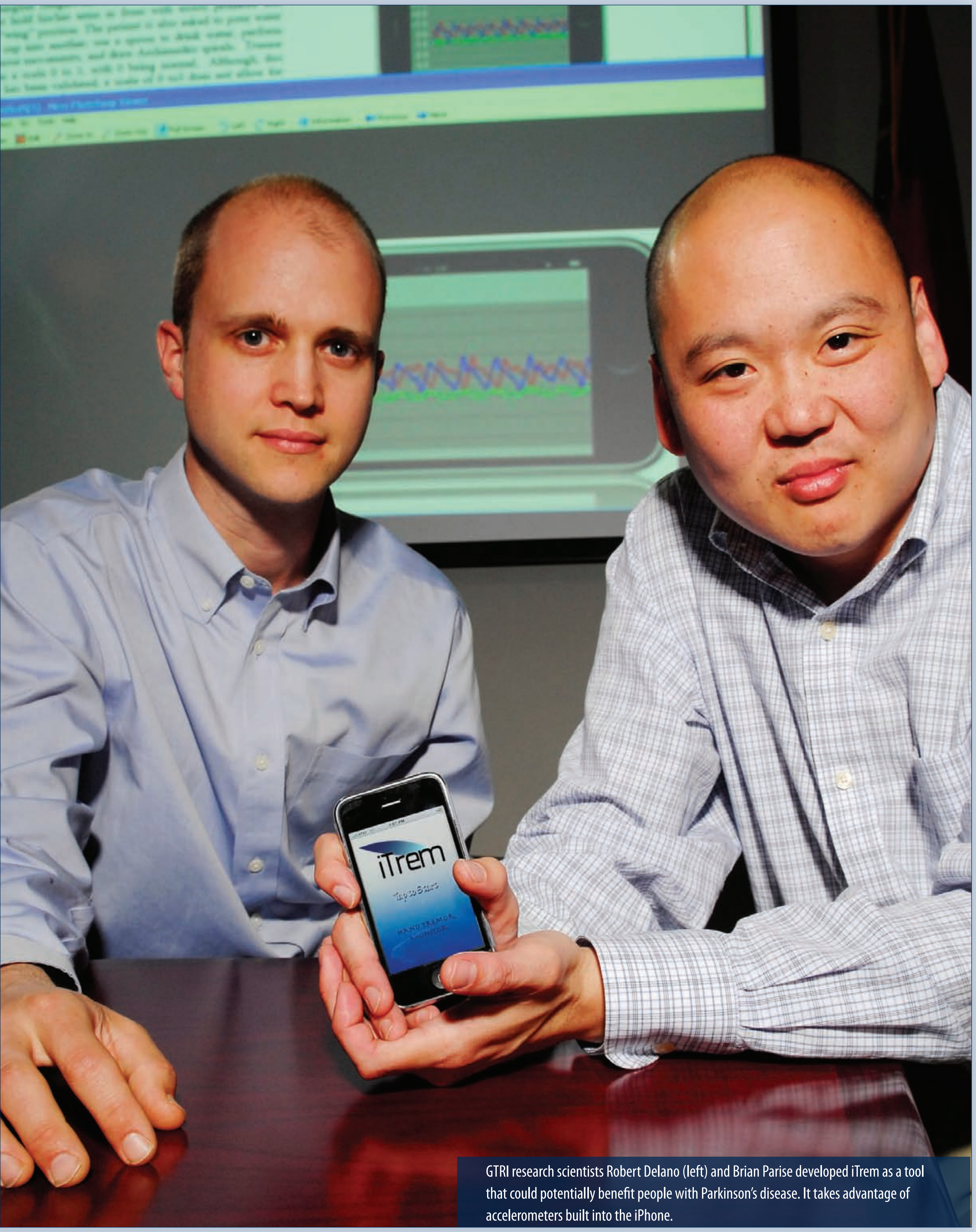
Utilizing Smartphones to Monitor Cancer Treatment and Parkinson's Disease

For individuals receiving treatment for cancer, complete blood counts are vital for assessing the degree of toxicity from treatment with chemotherapy or radiation, which places patients at high risk for serious infections and requires that they remain at home to prevent acquiring infections from public places.

Instead of making weekly visits to clinics or commercial laboratories to have blood drawn, patients may one day use a cell phone attachment and software being developed by biomedical engineers to measure platelet count, neutrophil count and hemoglobin levels in real time at home. The information can be obtained from a single drop of blood obtained via finger prick.

Analogous to at-home glucose monitors that diabetics use,

Photo: Gary Meek



GTRI research scientists Robert Delano (left) and Brian Parise developed iTrem as a tool that could potentially benefit people with Parkinson's disease. It takes advantage of accelerometers built into the iPhone.

the device – called the Quantum CBC – uses a cell phone-integrated microscope to analyze the blood, which is loaded into a disposable cartridge. The cartridge contains a channel with a fluorescent dye that binds to platelets and white blood cells, along with quantum dots targeted to neutrophils.

"Using this system, patients could test themselves whenever and wherever they desire to determine when they are at risk for infection, when they can leave their homes and when they require a transfusion," said Wilbur Lam, an assistant professor with a joint appointment in the Coulter Department and the Department of Pediatrics at Emory University. "This device will empower cancer patients, allowing them to take an active role in their treatment and enhance their quality of life."

Lam is collaborating on this project with Gang Bao, the Robert A. Milton Chair in Biomedical Engineering and College of Engineering Distinguished Professor at Georgia Tech. It is supported by the Coulter Foundation.

Also using smartphone technology, researchers at the Georgia Tech Research Institute (GTRI) have developed a novel iPhone application that may enable persons with Parkinson's disease to use the ubiquitous devices to collect data on hand and arm tremors and relay the results to medical personnel. The researchers believe the application could replace subjective tests now used to assess the severity of tremors, while potentially allowing more frequent patient monitoring without costly visits to medical facilities.

The program, known as iTrem, utilizes the iPhone's built-in accelerometer to collect data on a patient. The application directly tracks tremor information and in the future may use simple puzzle games to record tremor data, which will then be processed and transmitted. The GTRI development team presented a paper on iTrem in January at the 2011 International Conference on Health Informatics.

"We expect iTrem to be a very useful tool for patients and their caregivers," said Brian Parise, a research scientist who is principal investigator for the project along with Robert Delano, another GTRI research scientist. "And as a downloadable application, it also promises to be convenient and cost-effective."

iTrem will undergo a clinical study led by Stewart Factor, a professor of neurology at Emory University.

Improving Drug Dosing Following a Heart Attack

A research team led by Georgia Tech mechanical engineering assistant professor Craig Forest is designing a device to quickly and accurately personalize a patient's drug dosage to prevent blood clots that can cause heart attacks.

When someone experiencing heart attack symptoms arrives at an emergency room, he or she typically receives a standard dose of aspirin and/or clopidogrel to prevent further blood clotting. But that standard dose may not be the best dose for a given individual.

With Forest's device, a small blood sample is sent through a microchip containing a network of microfabricated capillaries that mimic the branching coronary arteries around the human heart. Because the branches contain flow restrictions of different sizes, the failure of blood to flow through the branches with smaller restrictions indicates that a higher drug dose may be required.

"This bedside device should be a huge improvement compared to the way dosage is determined today, which is by observing if the standard dosage leads to gastrointestinal bleeding, which means the administered drug dose was too large, or the patient has another heart attack, which means the dose was too small," said Forest.

Emory University Department of Emergency Medicine assistant

CardioMEMS

CardioMEMS, a graduate of Georgia Tech's ATDC startup accelerator, is a rising star in the medical device industry. The company has obtained approval from the U.S. Food and Drug Administration for one of its devices and is moving closer to agency approval on a second device.

Launched in 2001, CardioMEMS was co-founded by Jay Yadav, a cardiologist and director at the Cleveland Clinic Foundation at the time, and Mark Allen, a professor in Georgia Tech's School of Electrical and Computer Engineering. The company has pioneered a new class of monitoring devices for heart patients that combine wireless communications technology with microelectromechanical systems fabrication, providing doctors with more information while making monitoring less invasive for patients.

In 2006, CardioMEMS began marketing its first product, the EndoSure sensor, which measures blood pressure inside a repaired abdominal aortic aneurysm. The Atlanta-based company's second product is a sensor that wirelessly measures intracardiac pressure in people who suffer from congestive heart failure. Results from a clinical study in May 2010 showed a 40 percent reduction in hospitalizations when doctors used data from CardioMEMS' system to treat patients. (More information on CardioMEMS: www.cardiomems.com) professor Jeremy Ackerman and Georgia Tech Regents professor of mechanical engineering David Ku are working with Forest on this project, which is supported by the American Heart Association.

Improving Treatment of Chronic Wounds

When patients spend time in the hospital recovering, they may develop chronic wounds, such as pressure ulcers, stasis ulcers and diabetic ulcers. Approximately 20 percent of the hospitalized population in the United States suffers from these chronic wounds. By gathering information about the wounds over time, clinicians can identify wounds that may require different treatment.

Current methods and devices for wound measurement range from low-tech to high-tech. Simple ruler and tracing-based methods are easy to use but lack accuracy and reliability, and require contact with the wound. Devices using structured light and stereophotogrammetry methods are accurate and repeatable, but very expensive.

Stephen Sprigle, a professor in the Georgia Tech College of Architecture's Center for Assistive Technology and Environmental Access, and Thad Starner, an associate professor in the School of Interactive Computing at Georgia Tech, developed a low-cost, high-precision wound measurement camera. They received funding from the Georgia Research Alliance, tested the device at Atlanta's Shepherd Center rehabilitation hospital and recently licensed it to a medical technology company.

The hand-held device, which could be used by hospitals, nursing homes and home health agencies, quickly determines and captures information on wound boundaries and wound area. The device provides fast, accurate and repeatable digital documentation of wound progression, a necessary component to validate payment from insurance and government agencies.

Improving Rehabilitation for Hand Injuries and Balance Disorders

Starner also is involved in the development of Mobile Music Touch, a device originally designed to teach people to quickly learn to play a musical instrument – but which is currently being investigated for use in hand rehabilitation. The device consists of a leather athletic glove with a small plastic box on the back and vibration motors attached to each finger. Wireless impulses from a computer, MP3 player or cell phone transmit signals to the device, causing a specific finger to vibrate. The user then presses that finger onto a key on an electronic keyboard, the key lights up and the note sounds.

Mobile Music Touch was created by Georgia Tech graduate student Kevin Huang. Currently, Starner, graduate student Tanya Markow, and architecture and computing associate professor Ellen Yi-Luen Do, are working with Deborah Backus, the associate director of spinal cord injury research at Shepherd Center, to investigate the device's potential for hand rehabilitation.

"When people are injured, they may go through intense depression," Markow says. "Music can bring them a level of pleasure and enjoyment, and that's important because folks are dealing with the psychological aspects of being injured. It's soothing and relaxing – a way to raise their spirits."

An initial study with Shepherd Center patients indicated significant improvement in both sensory response and motor skills. Researchers found it particularly surprising because people with spinal cord injuries do not typically experience further recovery more than a year after their injuries. The researchers also were surprised that patients said they were more conscious of their hands, suggesting a change in their nervous systems.

In the area of rehabilitation from balance disorders, Georgia Tech

MedShape Solutions

Medical devices developed by MedShape Solutions, a recent graduate of Georgia Tech's Advanced Technology Development Center (ATDC), are impacting the U.S. orthopedic market. Georgia Tech professor Ken Gall, who has a joint appointment in the School of Materials Science and Engineering and the School of Mechanical Engineering, co-founded the company.

MedShape utilizes shape-memory polymers to easily insert devices into the body in a temporary compressed shape and then trigger them for deployment to the optimal functional shape. Initial applications of the technology involved the minimally invasive repair and reconstruction of injured or worn ligaments and tendons.

"Before contemplating any new product development, we work hard to understand the basic science surrounding any clinical issue we intend to address," said Gall. "As a result, MedShape is solving significant problems in the field of orthopedics."

MedShape's Morphix suture anchor helps clinicians reattach soft tissue to the bone during surgery to repair a rotator cuff or transfer a tendon in the foot. The ExoShape device simplifies and improves soft tissue graft fixation during knee ligament reconstructive surgery. The company's DynaNail intramedullary ankle fusion nail was designed for ankle fusion procedures, which are performed to relieve pain in patients with severely degenerated ankle joints. The DynaNail device adapts to changes in the surrounding bone to increase potential for successful joint fusion. All three devices have been approved by the U.S Food and Drug Administration. (More information on MedShape: www.medshapesolutions.com)

Photo: Gary Meek

Emory University Dizziness and Balance Center physical therapist Courtney Hall and Georgia Tech electrical and computer engineering assistant professor Pamela Bhatti inspect the HAMMS device Bhatti designed. The device uses inexpensive gyroscopes embedded in a visor to monitor patients during in-home vestibular rehabilitation exercises.

GTRI Medical Device Test Center

Researchers in the Georgia Tech Research Institute's (GTRI) Medical Device Test Center study how exposure to electromagnetic emissions may affect implanted and externally-worn medical devices. The center examines the interactions between medical devices and security and logistical systems – including electronic article surveillance systems and tag deactivators, radio frequency identification systems and airport metal detectors – and helps manufacturers improve compatibility. Collaborative testing with manufacturers helps improve device performance while meeting U.S. Food and Drug Administration requirements.

Center researchers have tested more than 800 medical devices, including pacemakers, implantable cardioverter defibrillators, neurostimulators, glucose monitors, drug infusion pumps, cardiac monitors, ventricular assist devices, programmable valves and implantable hearing devices.

In the center, medical devices are tested using a standardized protocol that simulates how people typically interact with security and logistical systems. The device being tested is mounted in or on a torso simulator containing saline solution that simulates the electrical characteristics of body tissue and fluid. Researchers use a computer-controlled positioner to move the torso simulator along an automated track, exposing the medical device to representative security and logistical systems. Different orientations of the device to the source emissions are used to represent the different ways people may come into contact with such fields in real-world situations. (More information on the Medical Device Test Center: http://bit.ly/osDQzR) electrical and computer engineering assistant professor Pamela Bhatti is working on a system that uses inexpensive gyroscopes embedded in a visor to monitor patients during in-home rehabilitation exercises. These vestibular rehabilitation exercises can improve balance, thus reducing dizziness, disorientation and blurred vision during head movement, and ultimately the number of falls.

Typically, a physical therapist guides a patient through vestibular rehabilitation exercises and verifies proper execution, but the patient is unsupervised for in-home exercises. Bhatti's head angular motion-monitoring system (HAMMS) uses microelectronics and motion sensors to instantaneously capture angular head rotations during exercises in a user-friendly and untethered fashion.

With a grant from the Atlanta Clinical & Translational Science Institute, Bhatti will use HAMMS as a data-logging tool to study the execution of in-home gaze stabilization exercises by patients in the Emory University Dizziness and Balance Center.

"This device provides a user-friendly technique for tracking and optimizing rehabilitation exercises with real-time performance feedback, which I believe will result in improved outcomes, improved monitoring and reduced cost," said Bhatti.

Surgical Devices

In the area of minimally invasive cardiac surgery, researchers have developed a technology that simplifies and standardizes the technique for opening and closing the beating heart during surgery.

Apica Cardiovascular, a Georgia Tech and Emory University medical device startup, licensed the technology from the institutions. The firm recently received a $5.5 million investment to further develop the system, which will make the transapical access and closure procedure required for delivering therapeutic devices to the heart more routine for cardiac surgeons. The goal is to expand the use of surgery techniques that are less invasive and do not require stopping the heart.

With research and development support from the Coulter Foundation Translational Research Program and the Georgia Research Alliance, the company has already completed a series of pre-clinical studies to test the functionality of the device and its biocompatibility. James Greene currently serves as the CEO of the company, which has offices in Galway, Ireland, and in Atlanta.

The technology was invented by Ajit Yoganathan, Georgia Tech Regents professor and Wallace H. Coulter Distinguished Faculty Chair in Biomedical Engineering; Vinod Thourani, an associate professor of surgery and associate director of the Structural Heart Center in Emory University's Division of Cardiothoracic Surgery; Jorge H. Jimenez, chief technology officer of the company, who received his Ph.D. from the Coulter Department; and Thomas Vassiliades, formerly an associate professor of cardiothoracic surgery at Emory University.

Through another Georgia Tech-Emory partnership, researchers have developed a hand-held device called SpectroPen to help surgeons see the edges of tumors in real time during surgery. Statistics indicate that complete removal, or resection, of most solid tumors is the single most important predictor of patient survival.

With funding from the National Institutes of Health, SpectroPen was designed by Coulter Department professor Shuming Nie and associate professor May Dongmei Wang. The researchers recently launched a startup company called SpectroPath to further develop and commercialize this technology.

Examining Medical Device Failures

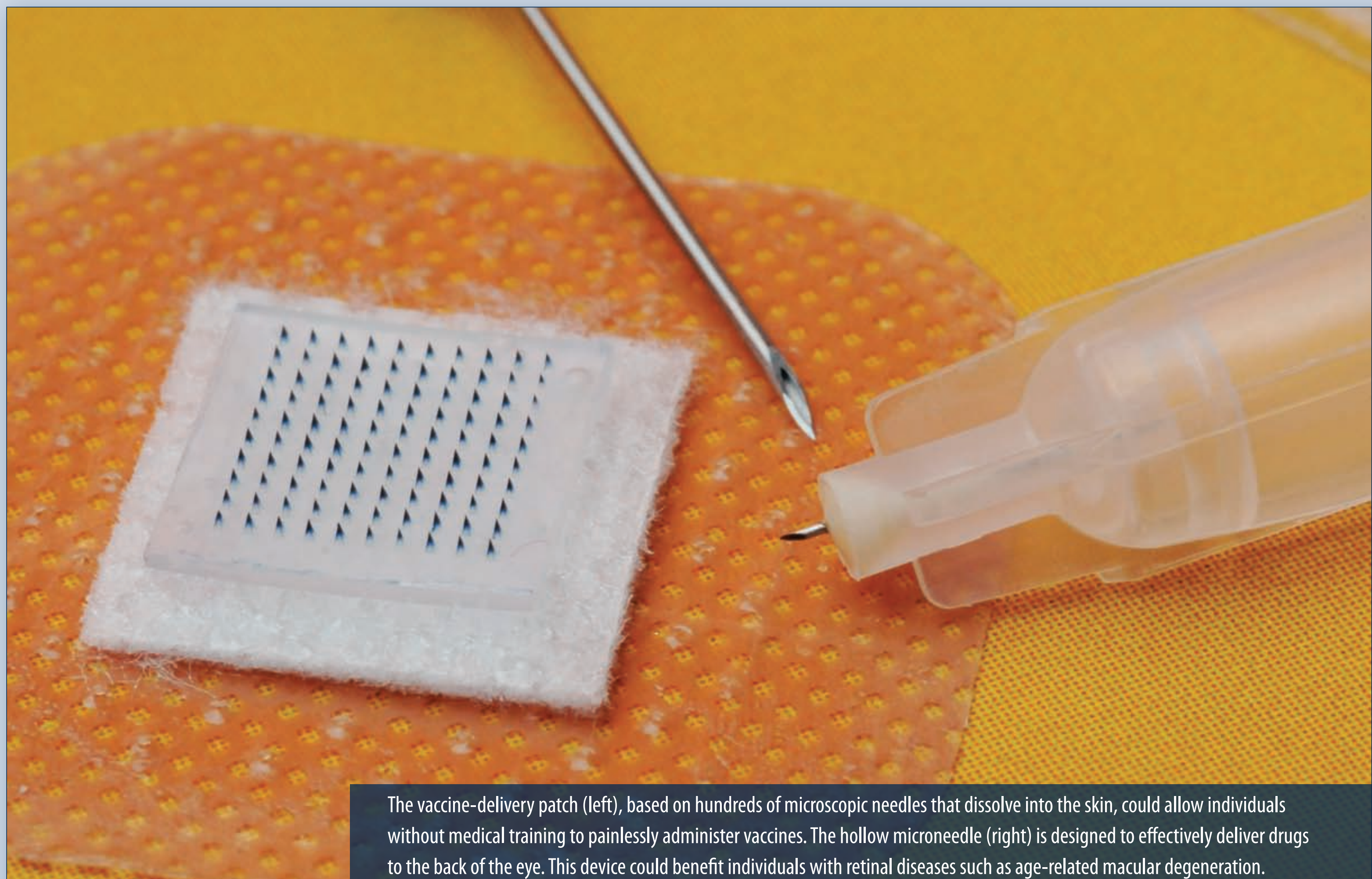
Operational failures have a significant impact on the medical device industry. These failures occur when a medical device has quality problems, such as lack of effectiveness, durability or safety. Manpreet Hora, an assistant professor in the College of Management at Georgia Tech, focuses his research on operational risk, investigating trends related to operational failures in the medical device industry.

Hora and David Maslach, a postdoctoral researcher in the Richard Ivey School of Business at the University of Western Ontario, have examined thousands of medical devices approved by the U.S. Food and Drug Administration and introduced to the market between 1998 and 2010 by 825 companies. Their dataset contains more than 95,000 new product introductions and more than 428,000 reported adverse events.

"Our preliminary analysis shows that an increased amount of time between product failures drives the success of a medical device firm's future products, but the number of new products a firm introduces does not impact the failure rate of subsequent products," said Hora.

While product failures have negative implications, they could also be a firm's competitive advantage. Failures provide an opportunity to learn and to avoid or eliminate practices that contributed to the failure, according to the researchers. Initial results of the researchers' analysis were presented in August 2011 at the Academy of Management Annual Meeting.

Photo: Gary Meek



The vaccine-delivery patch (left), based on hundreds of microscopic needles that dissolve into the skin, could allow individuals without medical training to painlessly administer vaccines. The hollow microneedle (right) is designed to effectively deliver drugs to the back of the eye. This device could benefit individuals with retinal diseases such as age-related macular degeneration.

The device detects tiny nanoparticles coupled to an antibody that sticks to molecules on the outsides of tumor cells. Nie and his collaborators have shown that the SpectroPen can detect tumors smaller than one millimeter in rodents. The device was described in the October 2010 issue of the journal *Analytical Chemistry*.

Emory University radiology professor James Provenzale and surgeons at the University of Georgia's College of Veterinary Medicine are currently using this device during operations to remove naturally occurring tumors in dogs. University of Pennsylvania assistant professor of surgery Sunil Singhal is applying for approval to conduct clinical trials involving patients with lung cancer.

Drug and Vaccine Delivery Devices

A new vaccine-delivery patch based on hundreds of microscopic needles that dissolve into the skin could allow individuals without medical training to painlessly administer vaccines – while providing improved immunization against diseases such as influenza. These microneedle patches could simplify immunization programs by eliminating the use of hypodermic needles, and their "sharps" disposal and re-use concerns.

The National Institutes of Health recently awarded $10 million to Georgia Tech, Emory University and PATH, a Seattle-based nonprofit organization, to advance the technology. The five-year grant will be used to address key technical issues and advance the microneedle patch through a Phase I clinical trial. The grant will also be used to compare the effectiveness of traditional intramuscular injection of flu vaccine against administration of vaccine into the skin using microneedle patches.

"We believe this technology will increase the number of people being vaccinated, especially among the most susceptible populations," said Mark Prausnitz, a Regents professor in the Georgia Tech School of Chemical & Biomolecular Engineering. "If we can make it easier for people to be vaccinated and improve the effectiveness of the vaccine, we could significantly reduce the number of deaths caused every year by influenza."

Prausnitz is also working with Georgia Tech postdoctoral fellow Samirkumar Patel and Emory Eye Center professor Henry Edelhauser to develop a hollow microneedle that can effectively deliver drugs to the back of the eye. This device could benefit individuals with retinal diseases such as age-related macular degeneration, which can require injections on a monthly basis. Development of the device is supported by the National Institutes of Health and the Georgia Research Alliance.

Photo: Gary Meek

Jason DiSanto uses the Tongue Drive System to navigate an electric wheelchair through an obstacle course during a test at the Shepherd Center in Atlanta.

"Our hollow microneedle technology is less invasive than direct injection into the eye because the microneedle apparatus is an order of magnitude smaller than currently used intravitreal needles and its length is less than one millimeter," said Patel.

The hollow microneedle, fabricated from stainless steel, penetrates the white of the eye – called the sclera – to reach a unique location underneath it called the suprachoroidal space. Results published in the January 2011 issue of the journal *Pharmaceutical Research* showed for the first time that nanoparticles and microparticles can be delivered in this way to target drug delivery to the parts of the eye needing therapy in diseases like macular degeneration.

More recently, the researchers demonstrated that microneedle injections into the suprachoroidal space resulted in sustained concentrations of drugs and particles for several months, which could enable less frequent visits to the doctor for injections.

"Because we can use the microneedle to target a drug to this specific space in the eye, we believe we can minimize side effects while maximizing exposure of the drug to the tissues where it would be most effective," added Patel.

The researchers are currently forming a startup company based on the technology, which they plan to test in clinical trials in a few years.

Assistive Devices

Enhancing Mobility, Access for Persons with Disabilities

The Tongue Drive System is a wireless and wearable device that enables people with high-level spinal cord injuries to operate a computer and maneuver an electrically-powered wheelchair simply by moving their tongues. Maysam Ghovanloo, an associate professor in Georgia Tech's School of Electrical and Computer Engineering, and his team have been recruiting individuals with high-level spinal cord injuries to test the system at the Atlanta-based Shepherd Center and the Rehabilitation Institute of Chicago.

Trial participants receive a clinical tongue piercing and tongue stud that contains a tiny magnet embedded in the upper ball. Users wear a wireless headset outfitted with sensors that track the movement of the magnetic tracer in the mouth. Software running on an iPod interprets the tongue commands and translates the information into commands for the wheelchair or computer.

During the trial, participants repeat two test sessions during a six-week period that assess their ability to use the Tongue Drive System to operate a computer and navigate an electric wheelchair through an obstacle course.

"Based on previous studies, we expect that as users learn to use the system, they will move the computer cursor quicker and with more accuracy, and maneuver through the obstacle course faster and with fewer collisions," said Ghovanloo.

This research is supported by the National Institutes of Health, National Science Foundation, and Christopher and Dana Reeve Foundation.

Researchers led by Stephen Sprigle, director of the Rehabilitation Engineering and Applied Research Laboratory at Georgia Tech, also are designing devices to improve wheelchair users' experiences.

To help elderly users who propel their wheelchairs with their feet, the researchers have designed a wheelchair seat based on tension support that allows users to sit low enough in the chair for their feet to touch the ground. The seat, which was licensed by The Posture Works, offers buttock support while maintaining a wheelchair's folding capability.

For individuals with weak hands or poor hand sensation, it can be difficult to slow down or stop a manual wheelchair using friction on the hand rims attached to the wheels of the wheelchair. While earning his master's degree in industrial design at Georgia Tech, Jonathan Jowers designed a hands-on brake to help these wheelchair users slow down more easily and quickly, while reducing burning and fatigue.

Individuals with quadriplegia, paraplegia and muscular dystrophy have used the device to perform a series of deceleration maneuvers on a sloped surface. During the tests, the users were able to quickly and easily maintain speed, slow down and stop using the braking system.

In the Coulter Department, assistant professor Charlie Kemp is designing robots to help people with limited mobility perform everyday tasks. Kemp designed a robot named EL-E that can find and deliver items that are highlighted with a simple laser pointer.

The robot autonomously moves to an item selected with a green laser pointer, picks up the item and then delivers it to a selected person or location. EL-E can grasp and deliver several types of household items, including towels, pill bottles and telephones.

"Humans naturally point at things, but we aren't very accurate, so we use the context of the situation or verbal cues to clarify which object is important," said Kemp, who is also an adjunct professor in Georgia Tech's College of Computing. "Robots have some ability to retrieve specific, predefined objects, but retrieving generic everyday objects has been a challenge."

More recently, Kemp designed a robot named Dusty to retrieve small objects dropped on the floor. Using a wheelchair joystick, users drive Dusty to a position in front of an object and press a button. Dusty autonomously moves forward and scoops the object into a tray for delivery. The user can navigate the robot back and press the lift button, which commands Dusty to lift the tray to a comfortable height for the user to grasp the object.

In collaboration with the Emory ALS Center, Kemp's laboratory conducted a 20-person user study with individuals who have motor impairments. Participants were highly satisfied with Dusty, and found it easy to use.

When Alpharetta, Ga., company Access Product Marketing wanted to add a cane to its line of mobility devices, the company came to the Georgia Tech Research Institute (GTRI) for help. GTRI senior research scientist Brad Fain and his team designed a sturdy folding cane for the company.

The team designed the tip of the Hugo folding cane so that it could bear heavy loads and be highly resistive to slipping. The cane was successfully tested with 550 pounds of weight applied. The cane was also designed with an interchangeable handle that could be chosen by each user. The personalized handle feature came to the attention of the producers of the Fox television show, "House, M.D." The main character, Dr. Gregory House, used a Hugo folding cane with a customized handle in more than eight episodes.

Increasing Sense of Touch and Awareness

While using a cane can improve balance, wearing a glove with a vibrating fingertip might improve sense of touch. Georgia Tech researchers designed such a device and attached it to 10 healthy adult volunteers who performed common sensory and motor skill tasks, including two-point discrimination, single-point touch, texture discrimination and grasp tests. The results showed that the volunteers performed statistically better on all of the tasks when mechanical vibration was applied.

The device uses an actuator made of a piezoelectric material to generate high-frequency vibration. The actuator is attached to the side of the fingertip so that the palm-side of the finger remains free and the individual wearing the glove can continue to manipulate objects.

"This device may one day be used to assist individuals whose jobs require high-precision manual dexterity or those with medical conditions that reduce their sense of touch," said Jun Ueda, an assistant professor in the Woodruff School of Mechanical Engineering at Georgia Tech.

Minoru Shinohara, an associate professor in the School of Applied Physiology at Georgia Tech, and visiting scholar Yuichi Kurita worked with Ueda to design the device. Details were presented in May at the 2011 IEEE International Conference on Robotics and Automation in Shanghai.

In another project, researchers led by Bruce Walker, an associate professor of psychology and interactive computing at Georgia Tech, are helping to refine and improve an automated driving coach system designed at the Shepherd Center to aid drivers with brain injuries and other cognitive deficits.

The prototype system plugs into the car's power outlet. The driver receives intermittent verbal reminders to check mirrors, speed, and distance from other vehicles and objects. When the driver completes a task, he or she presses a button positioned on the car's armrest and then gets a brief verbal message of encouragement. If the system reminds a driver to complete a task and does not receive a response within three minutes, the system's prompts increase in frequency.

Walker's team gathered feedback from Shepherd Center patients who have used the automated driving coach to determine what speech and non-speech sounds and cues would be least intrusive and most helpful to its users. They are currently conducting evaluations of advanced versions of the system in the new driving simulator located in the Georgia Tech School of Psychology. They also consult with Centrafuse™, an Atlanta-based startup company that designs automotive software, on how to give the automated driving coach more functionality.

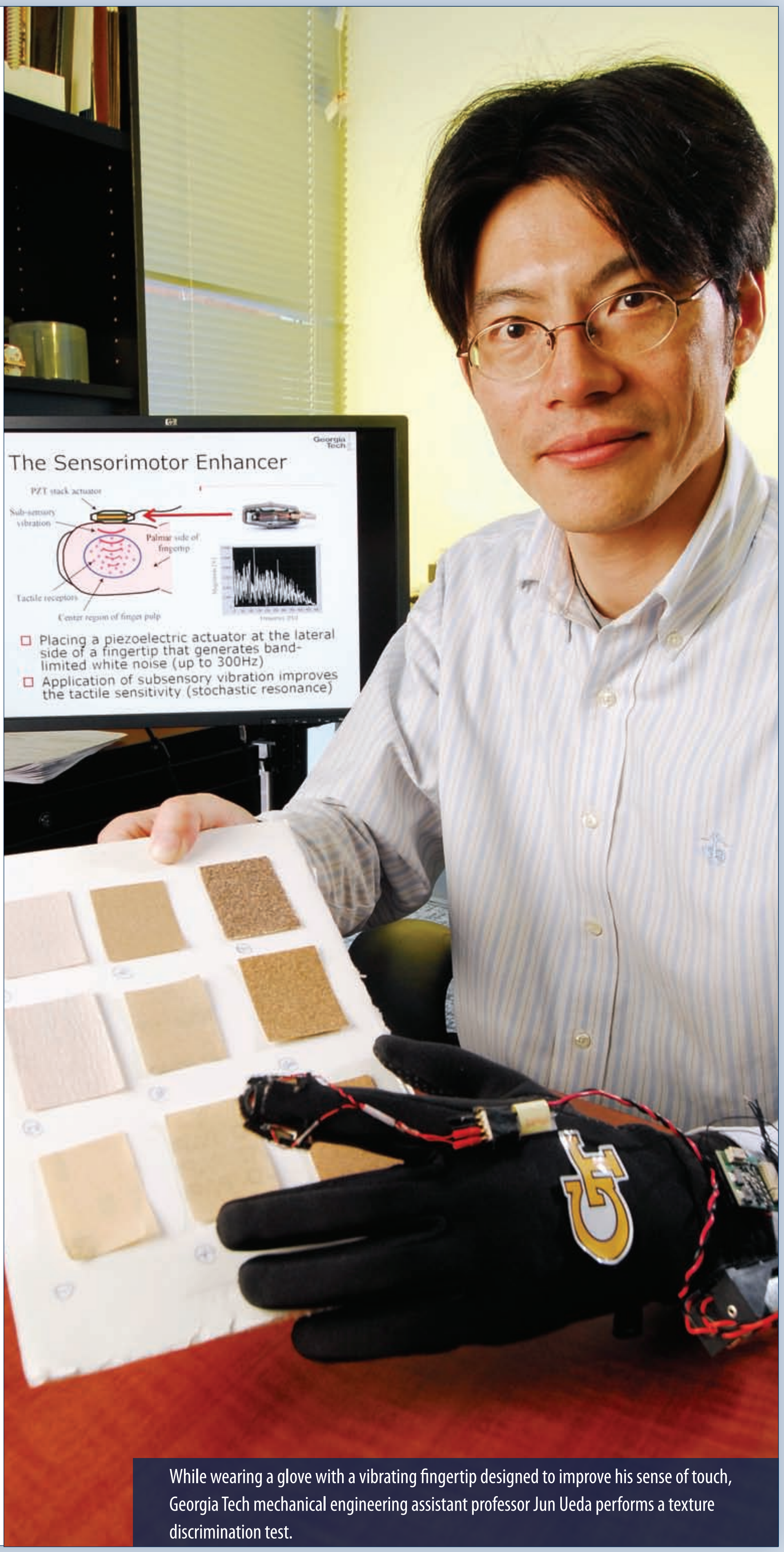
John Anschutz, the director of Shepherd's Assistive Technology Center, led the initial development of the device, with the help of driver rehabilitation specialist Michele Luther-Krug, vice president of technology Mike Jones and director of brain injury research Ron Seel.

The development of medical devices is a logical outgrowth of many research activities at Georgia Tech. Moving these devices from the laboratory into the clinic is becoming an increasingly important part of Georgia Tech's mission – and its collaborations with other institutions. The development and commercialization of medical devices supports Georgia Tech economic development goals and its mission of improving the human condition.

With design and prototyping support from the Global Center for Medical Innovation and commercialization support from the Georgia Research Alliance and Georgia Tech's VentureLab, Georgia Tech will continue to advance the medical device industry. rh

T.J. Becker, John Christensen, Quinn Eastman, Rick Robinson, Jane Sanders, David Terraso and John Toon also contributed to this article.

Photo: Gary Meek



While wearing a glove with a vibrating fingertip designed to improve his sense of touch, Georgia Tech mechanical engineering assistant professor Jun Ueda performs a texture discrimination test.

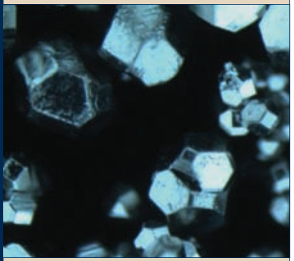
Researchers are developing a solid composite material composed of silver and diamond to help cool small, powerful microelectronics used in defense systems. The material promises exceptional thermal conductivity compared to materials currently used for this application.

Taking the Heat:

Silver-Diamond Composite Offers Unique Capabilities for Cooling Microelectronics

By Rick Robinson

Photo: Jason Nadler



Diamond, shown here, is the most thermally conductive natural material. Researchers are using it to help cool microelectronic devices in defense systems.

Researchers at the Georgia Tech Research Institute (GTRI) are developing a solid composite material to help cool small, powerful microelectronics used in defense systems. The material, composed of silver and diamond, promises exceptional thermal conductivity and reliability compared to materials currently used for this application.

The research is focused on producing silver-diamond thermal shims of unprecedented thinness – 250 microns or less. The ratio of silver to diamond in the material can be tailored to allow the shim to be bonded with minimal thermal-expansion stress to the high-power wide-bandgap semiconductors planned for next generation phased-array radars.

Thermal shims are needed to pull heat from these high-power semiconductors and transfer it to heat-dissipating devices such as fins, fans or heat pipes. Because the semiconductors work in very confined operating spaces, the shims must be made from a material that packs high thermal conductivity into a very thin component.

Diamonds provide the bulk of thermal conductivity, while silver suspends the diamond particles within the composite and contributes to thermal conductivity 25 percent better than copper. Tests indicate that the silver-diamond composite performs extremely well in two key areas: thermal conductivity and thermal expansion.

"We have already observed clear performance benefits – an estimated temperature decrease from 285 degrees Celsius to 181 degrees Celsius – using a material of 50 percent diamond in a 250-micron shim," said Jason Nadler, a GTRI research engineer who is leading the project.

The researchers are approaching diamond percentages that can be as high as 85 percent, in a shim less than 250 microns in thickness. These increased percentages of diamond are yielding even better performance results in prototype testing.

Diamond is the most thermally conductive natural material, with a rating of approximately 2,000 watts per meter Kelvin, which is a measure of thermal efficiency. Silver, which is among the most thermally conductive metals, has a significantly lower rating – 400 watts per meter Kelvin.

Nadler and his team use diamond particles, resembling grains of sand, that can be molded into a planar form. The problem is that a sand-like material doesn't hold together well. A matrix of silver – soft, ductile and sticky – is needed to keep the diamond particles together and achieve a robust composite material.

In addition, because the malleable silver matrix completely surrounds the diamond particles, it supports cutting the composite to the precise dimensions needed to form components like thermal shims. And silver allows those components to bond readily to other surfaces, such as semiconductors.

As any material heats up, it expands at its own individual rate, a behavior known as its coefficient of thermal expansion (CTE). When structures made from different materials are joined – such as a wide-bandgap semiconductor and a thermal shim – it's vital that their thermal-expansion coefficients be identical.

Diamond has a very low coefficient of thermal expansion of about two parts per million/Kelvin (ppm/K). But the materials used to make wide-bandgap semiconductors – such as silicon carbide or gallium nitride – have higher CTEs, generally in the range of three to five ppm/K.

By adding in just the right percentage of silver, which has a CTE of about 20 ppm/K, the GTRI team can tailor the silver-diamond composite to expand at the same rate as the semiconductor material. By matching thermal-expansion rates during heating and cooling, the researchers have enabled the two materials to maintain a strong bond.

Unlike metals that conduct heat by moving electrons, diamond conducts heat by means of phonons – vibrational wave packets that travel through crystalline and other materials. Introducing silver between the diamond-particle interfaces helps phonons move from particle to particle and supports thermal efficiency.

"It's a challenge to use diamond particles to fill space in a plane with high efficiency and stability," Nadler said. "In recent years, we've built image-analysis and other tools that let us perform structural morphological analyses on the material we've created. That data helps us understand what's actually happening within the composite – including how the diamond-particle sizes are distributed and how the silver actually surrounds the diamonds."

A remaining hurdle involves the need to move beyond performance testing to an in-depth analysis of the silver-diamond material's functionality. Nadler's aim is to explain the thermal conductivity of the composite from a fundamental materials standpoint, rather than relying solely on performance results.

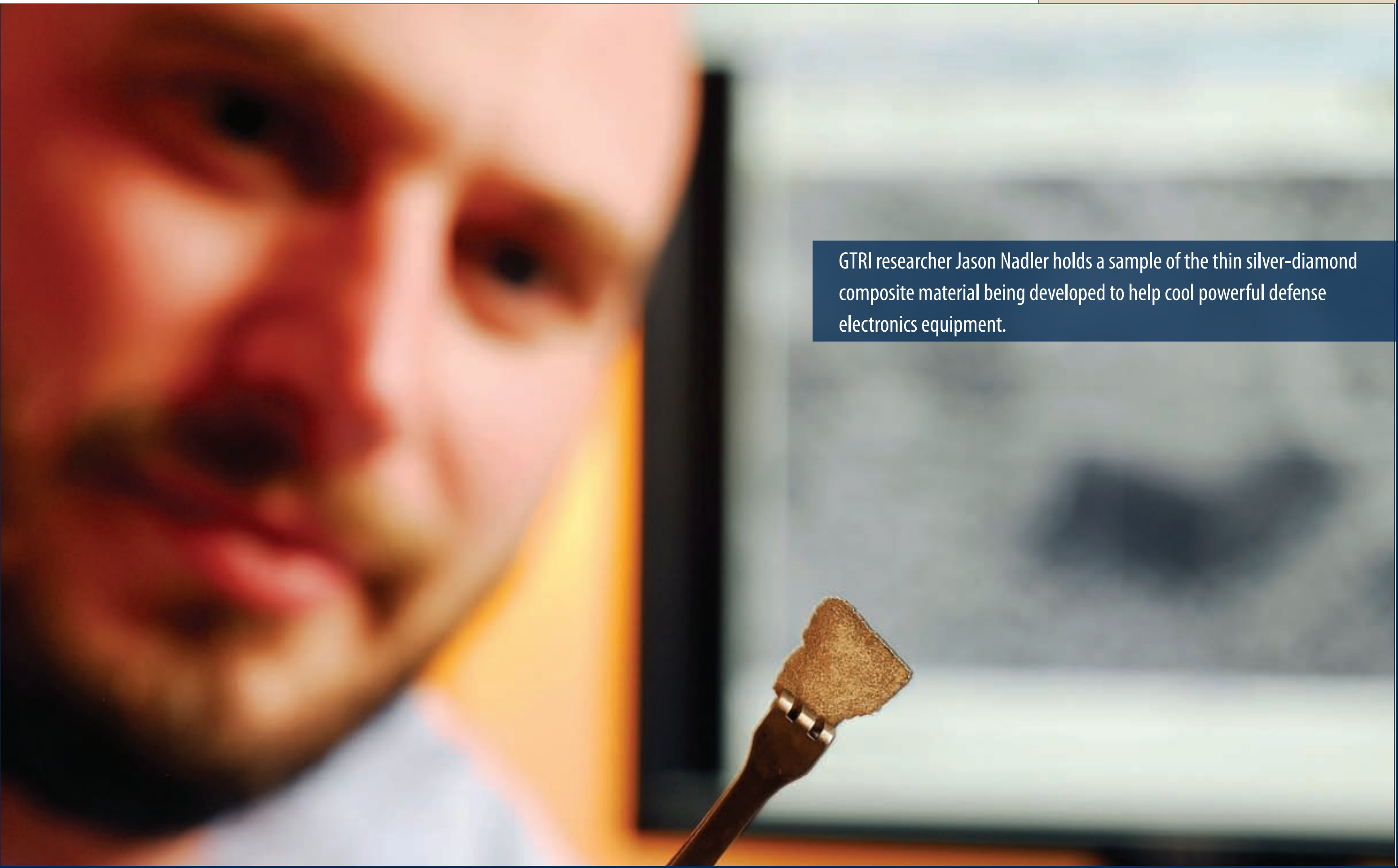
The extremely small size of the thermal shims makes such in-depth testing difficult, because existing testing methods require larger amounts of material. However, Nadler and his team are evaluating several test bed technologies that hold promise for detailed thermal-conductivity analysis. rh

CONTACT

Jason Nadler
jason.nadler@gtri.gatech.edu

"It's a challenge to use diamond particles to fill space in a plane with high efficiency and stability. In recent years, we've built image-analysis and other tools that let us perform structural morphological analyses on the material we've created. That data helps us understand what's actually happening within the composite."

— Jason Nadler, research engineer at the Georgia Tech Research Institute



GTRI researcher Jason Nadler holds a sample of the thin silver-diamond composite material being developed to help cool powerful defense electronics equipment.

Photo: Gary Meek

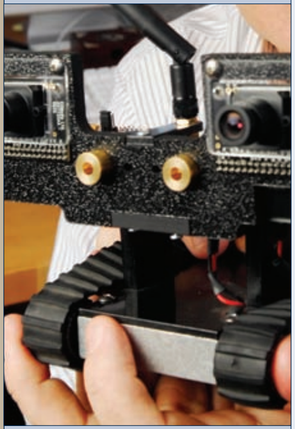
As part of a project sponsored by the U.S. Army Research Laboratory, researchers are giving autonomous robots the ability to work together to explore and map the interiors of buildings. Aside from soldiers, the capability could also help firefighters and other first responders.

Team Robot:

Researchers Demonstrate Autonomous Vehicles that Collaborate to Explore and Map

By Rick Robinson

Photo: Gary Meek



Researchers are using teams of small autonomous robots that are able to work together to map the interiors of buildings.

There isn't a radio-control handset in sight as several small robots roll briskly up the hallways of an office building. Working by themselves and communicating only with one another, the vehicles divide up a variety of exploration tasks, and within minutes have transmitted a detailed floor map to humans nearby.

This isn't a future-tech scenario. This advanced autonomous capability has been developed by a team from the Georgia Institute of Technology, the University of Pennsylvania and the California Institute of Technology/Jet Propulsion Laboratory (JPL).

"When first responders – whether it's a firefighter in downtown Atlanta or a soldier overseas – confront an unfamiliar structure, it's very stressful and potentially dangerous because they have limited knowledge of what they're dealing with," said Henrik Christensen, a team member who is a professor in the Georgia Tech College of Computing and director of the Robotics and Intelligent Machines Center. "If those first responders could send in robots that would quickly search the structure and send back a map, they'd have a much better sense of what to expect and they'd feel more confident."

The ability to map and explore simultaneously represents a milestone in the Micro Autonomous Systems and Technology (MAST) Collaborative Technology Alliance Program, a major research initiative sponsored by the U.S. Army Research Laboratory. The five-year program is led by BAE Systems and includes numerous principal and general members composed largely of universities.

MAST's ultimate objective is to develop technologies that will enable palm-sized autonomous robots to help humans deal with civilian and military challenges in confined spaces. The program's vision involves collaborative teams of tiny devices that could roll, hop, crawl or fly just about anywhere, carrying sensors that detect and send back information critical to human operators.

The wheeled platforms used in this experiment measure about one foot square. But MAST researchers are working toward platforms small enough to be held in the palm of one hand. Fully autonomous and collaborative, these tiny robots could swarm by the scores into hazardous situations.

The building mapping experiment, developed by the Georgia Tech MAST processing team, combines navigation technology developed by Georgia Tech with vision-based techniques from JPL and network technology from the University of Pennsylvania.

In addition to Christensen, members of the Georgia Tech processing team involved in the demonstration include Professor Frank Dellaert of the College of Computing and graduate students Alex Cunningham, Manohar Paluri and John G. Rogers III. Regents professor Ronald C. Arkin of the College of Computing and Tom Collins of GTRI are also members of the Georgia Tech processing team.

In the experiment, the robots perform their mapping work using two types of sensors – a video camera and a laser scanner. Supported by onboard computing capability, the camera locates doorways and windows, while the scanner measures walls. In addition, an inertial measurement unit helps stabilize the robot and provides information about its movement.

Data from the sensors are integrated into a local area map that is developed by each robot using a graph-based technique called simultaneous localization and mapping (SLAM). The SLAM approach allows an autonomous vehicle to develop a map of either known or unknown environments, while also monitoring and reporting on its own current location.

SLAM's flexibility is especially valuable in areas where global positioning system (GPS) service is blocked, such as inside buildings and in some combat zones, Christensen said. When GPS is active, human handlers can use it to see where their robots are. But in the absence of global location information, SLAM enables the robots to keep track of their own locations as they move.

"There is no lead robot, yet each unit is capable of recruiting other units to make sure the entire area is explored," Christensen explained. "When the first robot comes to an intersection, it says to a second robot, 'I'm going to go to the left if you go to the right.'"

In addition to the three universities, other MAST team participants are North Carolina A&T State University, the University of California at Berkeley, the University of Maryland, the University of Michigan, the University of New Mexico, Harvard University, the Massachusetts Institute of Technology and two companies: BAE Systems and Daedalus Flight Systems. rh

This research was sponsored by the Army Research Laboratory under Cooperative Agreement Number W911NF-08-2-0004. The views and conclusions contained in this document are those of the authors and should not be interpreted as representing the official policies, either expressed or implied, of the Army Research Laboratory or the U.S. government.

CONTACT

Henrik Christensen
hic@cc.gatech.edu

"When first responders – whether it's a firefighter in downtown Atlanta or a soldier overseas – confront an unfamiliar structure, it's very stressful and potentially dangerous because they have limited knowledge of what they're dealing with. If those first responders could send in robots that would quickly search the structure and send back a map, they'd have a much better sense of what to expect and they'd feel more confident."

— Henrik Christensen, professor in the College of Computing

Henrik Christensen, a professor in the Georgia Tech College of Computing and director of the Robotics and Intelligent Machines Center, is part of a team of researchers developing new mapping and exploration capabilities for robots.

Photo: Gary Meek

News Media Cover Work of Georgia Tech Researchers

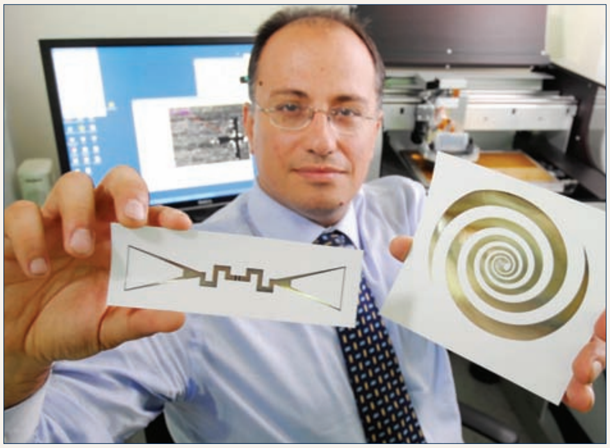
Hundreds of news outlets reported on Georgia Tech research aimed at capturing and harnessing energy transmitted by such sources as radio and TV transmitters, cell phone networks and satellite communications systems. Scavenging this ambient energy from the air could provide a new way to power networks of wireless sensors, microprocessors and communications chips. Devices to capture the energy are printed on paper or polymer, greatly reducing the cost. Media outlets covering the research included the *Boston Globe*, *ComputerWorld*, *Discover Magazine*, Discovery News, *Electronic Design News*, *EE Times*, ElectroIQ, Engadget, *Fast Company*, Gizmag, MSNBC.com, *Nano Magazine*, New Electronics, *PC World*, *Popular Science*, *TechJournal South* and the *Wall Street Journal*. Manos Tentzeris in the School of Electrical and Computer Engineering is the lead researcher. (See the story on page 4 of this issue of *Research Horizons*.)

A broad range of news outlets covered a $10 million grant received by the Georgia Tech Research Institute (GTRI) to lead implementation efforts for the five-year Homeland Open Security Technology (HOST) program. The HOST program, funded by the Department of Homeland Security, will investigate open source and open cyber security methods, models and technologies, and identify viable and sustainable approaches that support national cyber security objectives. Media reporting on this project included the *Atlanta Business Chronicle*, the *Chronicle of Higher Education, Defense Daily, Electronic Design News (EDN), Government Computer News,* Homeland Security News, LiveScience.com, MSNBC.com, *Network World, PC Magazine* and *SC Magazine*. Joshua Davis is leading the project in GTRI. (See the story on page 45 of this issue of *Research Horizons*.)

As part of a project sponsored by the U.S. Army Research Laboratory, Georgia Tech researchers are part of a team of universities and companies collaborating to give autonomous robots the ability to work together to explore and map the interiors of buildings. Aside from military personnel, the capability could also help firefighters and other first responders. News outlets reporting on this project include CNET, Communications of the ACM, *Electronic Products,* Engadget, *Military & Aerospace Electronics, Popular Mechanics, Popular Science, R&D Magazine,* Robotics Trends, *Space Daily* and *Wired*. The collaborative mapping project is being led by Henrik Christensen in Georgia Tech's College of Computing. (See the story on page 24 of this issue of *Research Horizons*.)

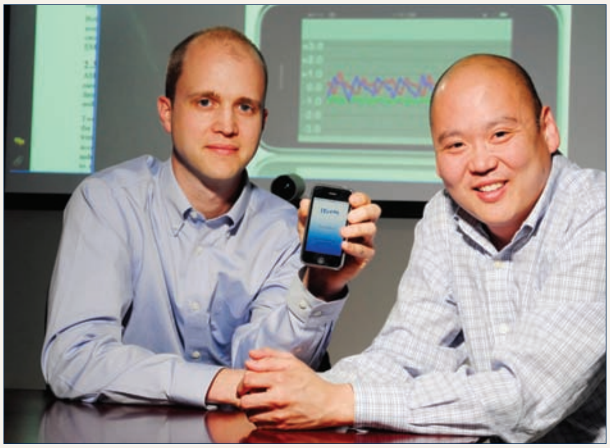
Georgia Tech Research Institute (GTRI) researchers have developed a new iPhone application that may enable persons with Parkinson's disease and certain other neurological conditions to use the ubiquitous devices to collect data on hand and arm tremors and relay the results to medical personnel. The researchers believe the application could replace subjective tests now used to assess the severity of tremors, while potentially allowing more frequent patient monitoring without costly visits to medical facilities. Media outlets covering this work included Communications of the ACM, *the Dallas Morning News, The Engineer, Medical News, R&D Magazine,* Science Daily and WABE-FM. GTRI research scientists Brian Parise and Robert Delano are developing the application. (See the story on page 14 of this issue of *Research Horizons*.)

Photo: Gary Meek



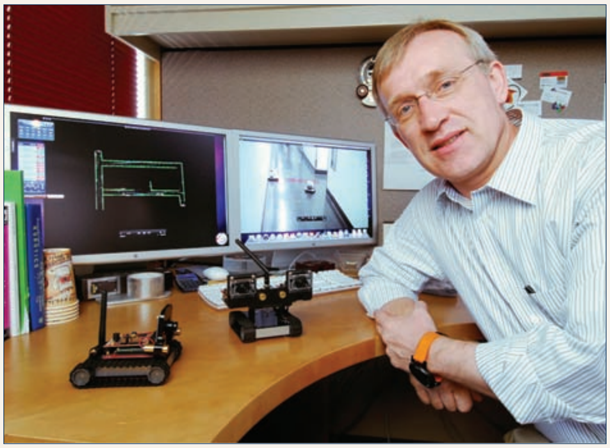
School of Electrical and Computer Engineering professor Manos Tentzeris holds a sensor (left) and an ultra-broadband spiral antenna for energy-scavenging applications. Both were printed on paper using inkjet technology.

Photo: Gary Meek



GTRI research scientists Robert Delano (left) and Brian Parise developed iTrem as a tool that could potentially benefit people with Parkinson's disease. It takes advantage of accelerometers built into the iPhone.

Photo: Gary Meek



Henrik Christensen, a professor in the Georgia Tech College of Computing, is part of a team of researchers developing new mapping and exploration capabilities for robots.

Georgia Tech Faculty and Staff Receive Recognition

The American Chemical Society named College of Sciences dean **Paul Houston** and School of Chemistry and Biochemistry professor **David Sherrill** as Fellows.

Kimberly Kurtis, professor in the School of Civil and Environmental Engineering, was elevated to Fellow by the American Ceramics Society.

School of Industrial and Systems Engineering professor **William J. "Bill" Cook** was named a member of the National Academy of Engineering and a Fellow in the Institute for Operational Research and Management Sciences.

Biomedical engineering professor **Barbara Boyan** was named a Fellow of the International Team for Implantology.

Spyros Pavlostathis, professor of environmental engineering, became a Fellow of the Water Environment Federation.

The Board of Regents of the University System of Georgia appointed School of Chemical & Biomolecular Engineering professor **Mark Prausnitz**, and School of Chemistry and Biochemistry professors **Seth Marder** and **Gary Schuster**, as Regents professors. Appointed as Regents researchers were **Gisele Bennett**, director of GTRI's Electro-Optical Systems Laboratory and a professor of electrical and computer engineering, and **Suzanne Eskin**, principal research scientist in the Department of Biomedical Engineering.

Bruce Walker became a senior member of the Association of Computing Machinery.

President Barack Obama named President **G. P. "Bud" Peterson** to the Advanced Manufacturing Partnership steering committee.

The American Psychological Association Committee on Aging presented its award for the Advancement of Psychology and Aging to **Anderson Smith**, Regents professor of psychology and senior vice provost for academic affairs.

Chemical & biomolecular engineering professor **William Koros** was selected as the 2011 Institute Lecturer by the American Institute of Chemical Engineers.

Psychology professor **Chris Hertzog** received the 2011 Margret M. and Paul B. Baltes Distinguished Research Achievement Award from Division 20 of the American Psychological Association.

Vijay Vaziran, professor in the School of Computer Science, received a 2011 Guggenheim Fellowship.

Aerospace engineering associate professor **John-Paul Clarke** received the William Littlewood Memorial Lecture Award from SAE International and the American Institute of Aeronautics and Astronautics.

Nancy Nersessian, Regents professor with a joint appointment in the College of Liberal Arts and College of Computing, received the American Philosophical Society's Patrick Suppes Prize in Philosophy of Science.

GTRI senior research engineer **Patrick Dowdy** received a letter of commendation for excellence from the director of the U.S. Army's Integrated Air and Missile Defense Project Office.

Martha Grover, associate professor in the School of Chemical & Biomolecular Engineering, received the 2011 Computing and Systems Technology Outstanding Young Researcher Award from the American Institute of Chemical Engineers.

GTRI principal research associate **Jeff Moulton** was selected to serve on the Air Force Communications and Electronics Association International Cyber Committee.

Joseph B. Hughes, chair of the School of Civil and Environmental Engineering, was named the 2011 Engineer of the Year in Education by the Georgia Engineering Alliance.

Aerospace engineering research engineer **Michelle Kirby** received the 2010 Federal Aviation Administration Center of Excellence Faculty of the Year Award.

Ronald Rousseau, chair of the School of Chemical & Biomolecular Engineering, received the 2011 Mac Pruitt Award from the Council on Chemical Research.

At the Manufacturing Extension Partnership conference, two Enterprise Innovation Institute (EI^2) teams received awards. EI^2's Energy and Sustainability Services group won the Innovator of the Year Award. Staff members include **Bill Meffert, Matt Soderlund, Robert Hitch, Ed Hardison, Holly Grell-Lawe, Randy Green, Deann Desai, Mike Brown** and **Jessica Brown**. EI^2's Lean Consortium Team received the Practitioner of the Year award. Staff members include **Larry Alford, David Apple, Alan Barfoot, Tara Barrett, Sam Darwin, Danny Duggar, Art Ford, Tim Israel, Bill Nusbaum, Elliot Price, Bill Ritsch, Tom Sammon, Paul Todd** and **Derek Woodham**.

Mechanical engineering professor **Marti Hastings** received the 2011 Per Bruel Gold Medal for Noise Control and Acoustics from the American Society of Mechanical Engineers.

Mark Styczynski, an assistant professor in the School of Chemical & Biomolecular Engineering, received a 2011 Defense Advanced Research Projects Agency (DARPA) Young Faculty Award.

Brian German, assistant professor in aerospace engineering, received the Northrop Grumman Aerospace Systems Dean's Teaching Excellence Award.

Electrical and computer engineering professor **A.P. Sakis Meliopoulos** received the 2010 International George Montefiore Award.

GTRI senior director of communication **Kirk Englehardt** received the 2011 Chapter Champion Award from the Public Relations Society of America's Georgia Chapter. His team also received the Bronze Anvil Award of Commendation from the Public Relations Society of America.

Elsa Reichmanis, professor in chemical & biomolecular engineering, received the 2011 Distinguished Service Award from the American Chemical Society's Division of Polymeric Materials: Science and Engineering.

The National Center for Manufacturing Sciences named **Henrik Christensen**, professor in the School of Interactive Computing, to the Robotics Technology Consortium's Board of Directors.

Vigor Yang, chair of aerospace engineering, is vice president-elect of publications for the American Institute of Aeronautics and Astronautics.

Electrical and computer engineering professor **Rao Tummala** received the 2011 TechnoVisionary Award from the India Semiconductor Association.

Henry Sauermann, assistant professor of strategic management, won the Young Scholar Award at the DRUID annual conference.

School of Computer Science assistant professor **Nina Balcan** received a 2011 Microsoft Research Faculty Fellowship.

Jianjun (Jan) Shi, professor in the School of Industrial and Systems Engineering, received the Albert G. Holzman Distinguished Educator Award from the Institute of Industrial Engineers.

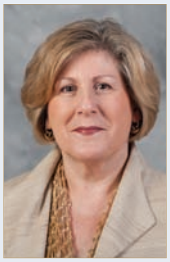
— Compiled by Abby Robinson


Gisele Bennett


Barbara Boyan


Henrik Christensen


Paul Houston


Nancy Nersessian


Mark Prausnitz


Anderson Smith

A study involving 10 different species of microorganisms provides direct experimental support for Darwin's 150-year-old hypothesis that the struggle for existence is stronger between more closely related species than among those distantly related.

Proving Darwin Right:

Study Supports Hypothesis of Stronger Competition Between More Closely Related Species

By Abby Robinson

Photo: Gary Meek

Lin Jiang, an assistant professor in the School of Biology, looks into a microscope at a protist species used in a study of competition among closely-related organisms.

A new study provides support for Darwin's 150-year-old hypothesis that the struggle for existence is stronger between more closely related species than among those distantly related. While ecologists generally accept the premise, this new study of competition among microorganisms contains the strongest direct experimental evidence yet to support its validity.

"We found that species extinction occurred more frequently and more rapidly between species of microorganisms that were more closely related, providing strong support for Darwin's theory, which we call the phylogenetic-limiting similarity hypothesis," said Lin Jiang, an assistant professor in the School of Biology at Georgia Tech.

The study was published online June 14, 2011, in the journal *Ecology Letters*. The work was supported by the National Science Foundation (NSF).

Jiang and his team – Cyrille Violle, formerly a postdoctoral fellow at Georgia Tech now at the Centre d'Ecologie Fonctionnelle et Evolutive in Montpellier, France, and Georgia Tech biology graduate student Zhichao Pu – conducted experiments with 10 common ciliated protist species in artificial, simplified ecosystems called microcosms. Diana Nemergut, an assistant professor in the Institute of Arctic and Alpine Research and the Environmental Studies Program at the University of Colorado at Boulder, helped the team generate a family tree of the 10 microorganisms to determine how closely related the species were.

"We selected bacterivorous ciliated protist microorganisms for this study because they rapidly reproduce, allowing us to examine species coexistence over multiple generations in a closed system during a period of a few weeks, which wouldn't be possible if we were testing the hypothesis with plants or animals," said Jiang.

The researchers set up 165 microcosms that contained either an individual protist species or a pairing of two species, along with three types of bacteria for the organisms to eat. They collected weekly samples from each microcosm and examined them under a microscope, recording the presence or absence of species. After 10 weeks, the researchers estimated the density of the protist species in each microcosm.

The study results showed that all species survived until the end of the experiment when alone in a microcosm. However, in more than half of the experiments in which protists were paired together, one of the two species dominated, leading to the extinction of the other species.

The researchers found that the frequency and speed of this extinction process – called competitive exclusion – was significantly greater between species that were more closely related. In addition, in microcosms where both competitors coexisted for the duration of the experiment, the abundance of the inferior competitor was reduced more as the phylogenetic relatedness between the two competitors increased.

The study also showed that the frequency of competitive exclusion was significantly greater between species that had similar mouth sizes.

"We documented the mouth size of each species because there is some evidence that this morphological trait affects the selectivity and uptake rate of prey particles, and we thought that similarity in mouth size might translate into the exploitation of similar bacterial resources and result in competitive exclusion," said Jiang.

While they found that phylogenetic relatedness predicted the likelihood of coexistence better than mouth size, the results suggest that other traits involved in resource uptake may also be important predictors of the outcomes of competitive interactions in ecological communities.

"This study is one step toward a better understanding of how phylogenetic relatedness influences species interactions," said Jiang. "We hope our experimental validation of the phylogenetic-limiting similarity hypothesis in microorganisms will encourage other ecologists to conduct additional studies with other types of organisms to further validate Darwin's hypothesis."

The phylogenetic-limiting similarity hypothesis is just one of the many ideas Darwin published in his 1859 book *The Origin of Species*. In this book, Darwin introduced his scientific theory that populations evolve over the course of generations through a process of natural selection. The book presented a body of evidence that the diversity of life arose by common ascent through a branching pattern of evolution. rh

This project is supported by the National Science Foundation (NSF) (Award No. DEB-0640416 and Ecosystems Award No. 0922267). The content is solely the responsibility of the principal investigator and does not necessarily represent the official views of the NSF.

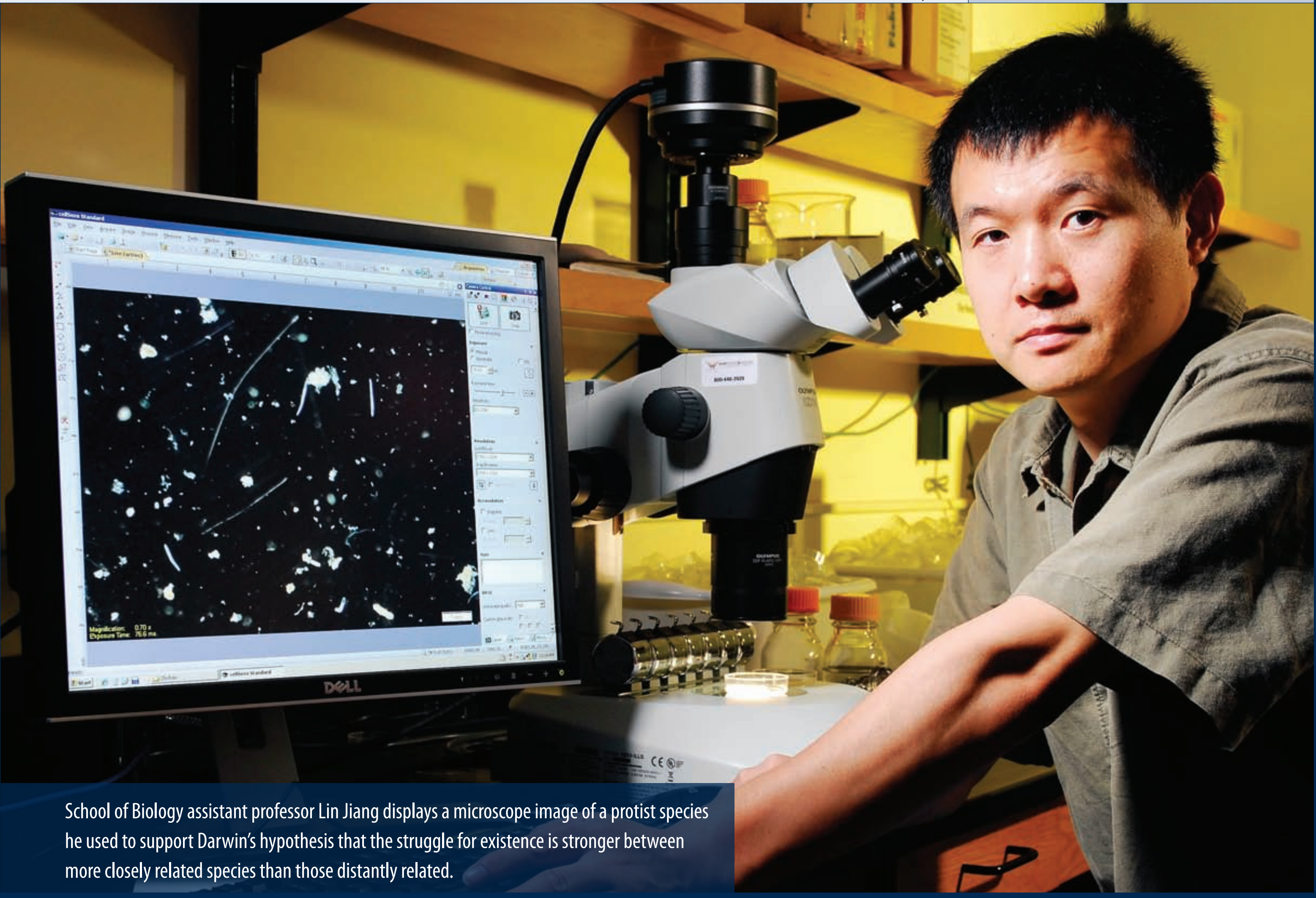
CONTACT

Lin Jiang
lin.jiang@biology.gatech.edu

"We found that species extinction occurred more frequently and more rapidly between species of microorganisms that were more closely related, providing strong support for Darwin's theory, which we call the phylogenetic-limiting similarity hypothesis."

— Lin Jiang, assistant professor in the School of Biology

Photo: Gary Meek



School of Biology assistant professor Lin Jiang displays a microscope image of a protist species he used to support Darwin's hypothesis that the struggle for existence is stronger between more closely related species than those distantly related.

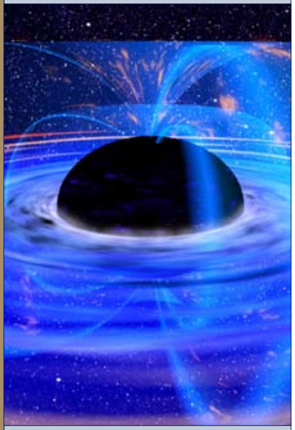
X-ray emissions from distant black holes are providing astrophysicists an important new test of a long-standing theory that describes the extreme physics occurring when matter spirals into these massive galactic objects.

Active Galactic Nuclei:

Astrophysicists Use X-ray Fingerprints to Study Eating Habits of Giant Black Holes

By John Toon

Image: NASA



This illustration shows a black hole surrounded by an accretion disk containing matter falling into it.

By studying X-rays emitted when superheated gases plunge into massive and distant black holes, Georgia Tech astrophysicists have provided an important test of a long-standing theory that describes the extreme physics occurring when matter spirals into these massive galactic objects.

Matter falling into black holes emits tremendous amounts of energy, which can escape as visible light, ultraviolet light and X-rays. This energy can also drive outflows of gas and dust far from the black hole, affecting the growth and evolution of galaxies containing the black holes. Understanding the complex processes that occur in these active galactic nuclei is vital to theories describing the formation of galaxies.

Though light cannot escape from black holes themselves, black holes with accretion disks – which are swirling clouds of matter about to enter the black hole – are among the most luminous objects in galaxies. By studying how the radiation and accretion disk interact, astrophysicists can learn about the extreme gravitational fields, magnetic forces and radiation processes close to these black holes.

"We reviewed data collected from space telescopes over the past few years and found that the more rapidly a black hole was gobbling up material, the more highly ionized the accretion disk was," said David Ballantyne, an assistant professor in Georgia Tech's School of Physics. "The simple theory of accretion disks predicts this, but the relationship we saw between the ionization and rate of accretion was different from what the theory predicted."

The researchers observed a linear dependence on the rate of accretion, while theory predicted a cubic dependence. In an article published online June 3, 2011, in *The Astrophysical Journal*, Ballantyne described the research and speculated about possible reasons for the difference. The research was supported in part by the National Science Foundation (NSF).

Astrophysicists don't have a detailed understanding of how the accretion process works, why black holes grow at different rates or what makes them stop growing. These questions are important because the growth of active galactic nuclei – which includes the black holes and their surrounding accretion disks – has broader effects on the galaxies of which they are part.

"The rapid accretion phase releases a lot of energy, not only in radiation, but also in outflows that drive gas out of a galaxy, which can shut off star formation and hold back the growth of the galaxy," said Ballantyne, a scientist in Georgia Tech's Center for Relativistic Astrophysics. "We could potentially learn something fundamental about the flow of energy through the accretion disk very close to the black hole. We could learn about the viscosity of this matter and how efficiently radiation transport takes place. These are very important questions in astrophysics."

X-rays are believed to originate from the inner-most portions of active galactic nuclei. As they pass through matter on its way into the black hole, the X-rays are altered by the materials in ways that astrophysicists can measure. In their study, Ballantyne and his collaborators were interested in studying the ionization state of the matter – which is related to the illumination – and were able to do so by analyzing the "fingerprint" the ionization left on the X-rays.

"From laboratory work, we understand the physics of how gas interacts with X-ray radiation because that's basically an atomic physics problem," he explained. "We can model what these fingerprints might look like on the X-rays, and compare that to the actual data to help us understand what's going on."

Ballantyne and collaborators Jon McDuffie and John Rusin studied 10 X-ray observations reported by other scientists from eight different active galactic nuclei. The observations were made using such space telescopes as Chandra and XMM.

The next step in the research will be to gather additional information from other studies of active galactic nuclei to see if the linear relationship Ballantyne's group measured holds up. The work may also lead to other techniques for learning about black holes and the accretion process.

"Black holes themselves are very simple, but what goes on around them can be very complex," Ballantyne said. "There is still a lot to be learned about how black holes get fueled and how some accrete slowly while others grow rapidly. The astrophysics of black holes is actually very important in determining what our universe looks like." rh

CONTACT

David Ballantyne
david.ballantyne@physics.gatech.edu

"There is still a lot to be learned about how black holes get fueled, and how some accrete slowly while others grow rapidly. The astrophysics of black holes is actually very important in determining what our universe looks like."

— David Ballantyne, assistant professor in the School of Physics

Georgia Tech astrophysicists have provided an important test of a long-standing theory that describes the extreme physics occurring when matter spirals into massive objects known as black holes. Here, assistant professor David Ballantyne poses with a NASA illustration of a black hole.

Photo: Gary Meek

Nanotechnology has facilitated a self-cleaning technique that could allow solid oxide fuel cells to be powered directly by coal gas at operating temperatures as low as 750 degrees Celsius. That could provide a cleaner and more efficient way to generate electricity from the nation's vast coal reserves.

Self-Cleaning Anodes:

Nanoparticle Technology Could Facilitate Cost-Effective Coal-Powered Fuel Cells

By John Toon

Photo: Gary Meek

(Above) Researchers are using laboratory-scale fuel cells to study a new type of self-cleaning anode that could allow the use of coal gas at relatively low temperatures.

Using barium oxide nanoparticles, researchers have developed a self-cleaning technique that could allow solid oxide fuel cells (SOFCs) to be powered directly by coal gas at operating temperatures as low as 750 degrees Celsius. The technique could provide a cleaner and more efficient alternative to conventional power plants for generating electricity from the nation's vast coal reserves.

Solid oxide fuel cells can operate on a wide variety of fuels, and use hydrocarbon gases directly – without a separate reformer. Traditional SOFCs rely on anodes made from nickel and a ceramic material known as yttria-stabilized zirconia (YSZ). However, carbon-containing fuels such as coal gas or propane quickly deactivate these Ni-YSZ anodes, clogging them with carbon deposits in a process known as "coking" – especially at lower operating temperatures.

To counter this problem, researchers have developed a technique for growing barium oxide nanostructures on the anodes. The structures adsorb moisture to initiate a water-based chemical reaction that oxidizes the carbon as it forms, keeping

Regents professor Meilin Liu (right) and postdoctoral researcher Mingfei Liu examine a button fuel cell used to evaluate a new self-cleaning anode material. The material could allow fuel cells to be powered by coal gas.

Photo: Gary Meek

the nickel electrode surfaces clean even when carbon-containing fuels are used at low temperatures.

"This could ultimately be the cleanest, most efficient and cost-effective way of converting coal into electricity," said Meilin Liu, a Regents professor in Georgia Tech's School of Materials Science and Engineering. "And by providing an exhaust stream of pure carbon dioxide, this technique could also facilitate carbon sequestration without the separation and purification steps now required for conventional coal-burning power plants."

The water-mediated carbon removal technique was reported June 21, 2011, in the journal *Nature Communications*. The research was supported by the U.S. Department of Energy's Office of Basic Energy Sciences, through the HeteroFoaM Center, an Energy Frontier Research Center. The work also involved researchers from Brookhaven National Laboratory, the New Jersey Institute of Technology and Oak Ridge National Laboratory.

Conventional coal-fired electric generating facilities capture just one-third of the energy available in the fuel. Fuel cells can convert significantly more of the energy, approximately 50 percent. If gas turbines and fuel cells could be combined into hybrid systems, researchers believe they could capture as much as 80 percent of the energy, reducing the amount of coal needed to produce a given amount of electricity, potentially cutting carbon emissions.

But that would only be possible if the fuel cells could run for long periods of time on coal gas, which now deactivates the Ni-YSZ anodes after as little as 30 minutes of operation.

The carbon removal system developed by the Georgia Tech-led team uses a vapor deposition process to apply barium oxide nanoparticles to the nickel-YSZ electrode. The particles, which range in size from 10 to 100 nanometers, form "islands" on the nickel that do not block the flow of electrons across the electrode surface.

When water vapor introduced into the coal gas stream contacts the barium oxide, it is adsorbed and dissociates into protons and hydroxide (OH) ions. The hydroxide ions move to the nickel surface, where they combine with the carbon atoms being deposited there, forming the intermediate COH. The COH then dissociates into carbon monoxide and hydrogen, which are oxidized to power the fuel cell, ultimately producing carbon dioxide and water. About half of the carbon dioxide is then recirculated back to gasify the coal to coal gas to continue the process.

"We can continuously operate the fuel cell without the problem of carbon deposition," said Liu, who is also co-director of Georgia Tech's Center for Innovative Fuel Cell and Battery Technologies.

The researchers also evaluated the use of propane to power solid oxide fuel cells using the new anode system. Because oxidation of the hydrogen in the propane produces water, no additional water vapor had to be added, and the system operated successfully for a period of time similar to the coal gas system.

Solid oxide fuel cells operate most efficiently at temperatures above 850 degrees Celsius, and much less carbon is deposited at higher temperatures. However, those operating temperatures require fabrication from expensive materials – and prevent solid oxide fuel cells from being cost-effective for many applications.

Reducing the operating temperatures is a research goal, because dropping temperatures to 700 or 750 degrees Celsius would allow the use of much less expensive components for interconnects and other important components. "Reducing the operating temperature significantly by eliminating the problem of carbon deposition could make these solid oxide fuel cells economically competitive," Liu said.

In addition to those already mentioned, the research team included Mingfei Liu, Lei Yang, Wentao Qin and Kevin Blinn from Georgia Tech; YongMan Choi and Ping Liu from Brookhaven National Laboratory; Haiyan Chen and Trevor Tyson from the New Jersey Institute of Technology; and Jianming Bai from Oak Ridge National Laboratory. rh

CONTACT

Meilin Liu
meilin.liu@mse.gatech.edu

"This could ultimately be the cleanest, most efficient and cost-effective way of converting coal into electricity. And by providing an exhaust stream of pure carbon dioxide, this technique could also facilitate carbon sequestration without the separation and purification steps now required for conventional coal-burning power plants."

— Meilin Liu, Regents professor in the School of Materials Science and Engineering

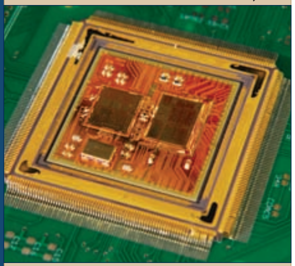
A five-year, $12 million project that involved an 11-member research team has developed a novel approach to space electronics that could change the way space vehicles and instruments are designed. The new capabilities are based on silicon-germanium (SiGe) technology, which can produce electronics that are highly resistant to both wide temperature variations and space radiation.

Silicon-Germanium in Space:

Project Pioneers New Extreme-Environment Electronics for NASA Spacecraft

By Rick Robinson

Photo: Gary Meek



This close-up image shows a remote electronics unit, a 16-channel sensor interface, developed for NASA using silicon-germanium microchips by an 11-member team led by Georgia Tech.

A five-year project led by Georgia Tech researchers has developed a novel approach to space electronics that could change how space vehicles and instruments are designed. The new capabilities are based on silicon-germanium (SiGe) technology, which can produce electronics that are highly resistant to both wide temperature variations and space radiation.

Titled "SiGe Integrated Electronics for Extreme Environments," the $12 million, 63-month project was funded by the National Aeronautics and Space Administration (NASA). In addition to Georgia Tech, the 11-member team included academic researchers from the University of Arkansas, Auburn University, University of Maryland, University of Tennessee and Vanderbilt University. Also involved in the project were BAE Systems, Boeing Co., IBM Corp., Lynguent Inc. and NASA's Jet Propulsion Laboratory.

"The team's overall task was to develop an end-to-end solution for NASA – a tested infrastructure that includes everything needed to design and build extreme-environment electronics for space missions," said John Cressler, who is a Ken Byers Professor in Georgia Tech's School of Electrical and Computer Engineering. Cressler served as principal investigator and overall team leader for the project.

A paper on the project findings appeared in December 2010 in *IEEE Transactions on Device and Materials Reliability, 2010*. During the past five years, work done under the project has resulted in some 125 peer-reviewed publications.

Unique Capabilities

Silicon-germanium alloys combine silicon, the most common microchip material, with germanium at nanoscale dimensions. The result is a robust material that offers important gains in toughness, speed and flexibility.

That robustness is crucial to silicon-germanium's ability to function in space without bulky radiation shields or large, power-hungry temperature control devices. Compared to conventional approaches, SiGe electronics can provide major reductions in weight, size, complexity, power and cost, as well as increased reliability and adaptability.

"Our team used a mature silicon-germanium technology – IBM's 0.5 micron SiGe technology – that was not intended to withstand deep-space conditions," Cressler said. "Without changing the composition of the underlying silicon-germanium transistors, we leveraged SiGe's natural merits to develop new circuit designs, as well as new approaches to packaging the final circuits, to produce an electronic system that could reliably withstand the extreme conditions of space."

At the end of the project, the researchers supplied NASA with a suite of modeling tools, circuit designs, packaging technologies and system/subsystem designs, along with guidelines for qualifying those parts for use in space. In addition, the team furnished NASA with a functional prototype – called a silicon-germanium remote electronics unit (REU), a 16-channel general purpose sensor interface. The device was fabricated using silicon-germanium microchips and has been tested successfully in simulated space environments.

A New Paradigm

Andrew S. Keys, center chief technologist at the Marshall Space Flight Center and NASA program manager, said the now-completed project has moved the task of understanding and modeling silicon-germanium technology to a point where NASA engineers can start using it on actual vehicle designs.

"The silicon-germanium extreme environments team was very successful in doing what it set out to do," Keys said. "They advanced the state-of-the-art in analog silicon-germanium technology for space use – a crucial step in developing a new paradigm leading to lighter weight and more capable space vehicle designs."

Keys explained that, at best, most electronics conform to military specifications, meaning they function across a temperature range of minus- 55 degrees Celsius to plus-125 degrees Celsius. But electronics in deep space are typically exposed to far greater temperature ranges, as well as to damaging radiation. The moon's surface cycles between plus-120 degrees Celsius during the lunar day to minus-180 degrees Celsius at night.

The silicon-germanium electronics developed by the extreme environments team has been shown to function reliably throughout that entire plus-120-to-minus-180-degree Celsius range. It is also highly resistant or immune to various types of radiation.

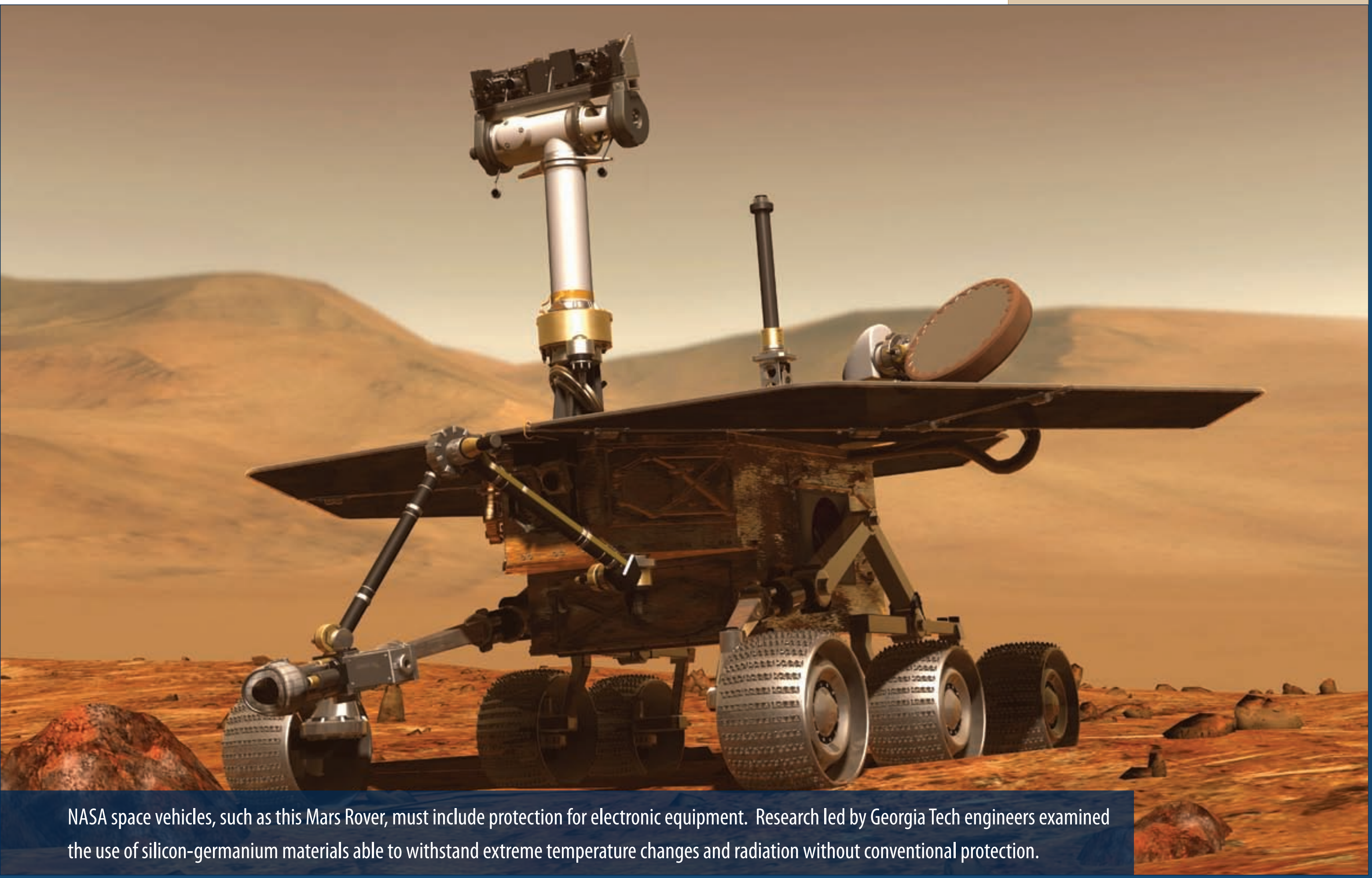
The conventional approach to protecting space electronics, developed in the 1960s, involves bulky metal boxes that shield de-

CONTACT

John Cressler
cressler@ece.gatech.edu

"Without changing the composition of the underlying silicon-germanium transistors, we leveraged SiGe's natural merits to develop new circuit designs, as well as new approaches to packaging the final circuits, to produce an electronic system that could reliably withstand the extreme conditions of space."

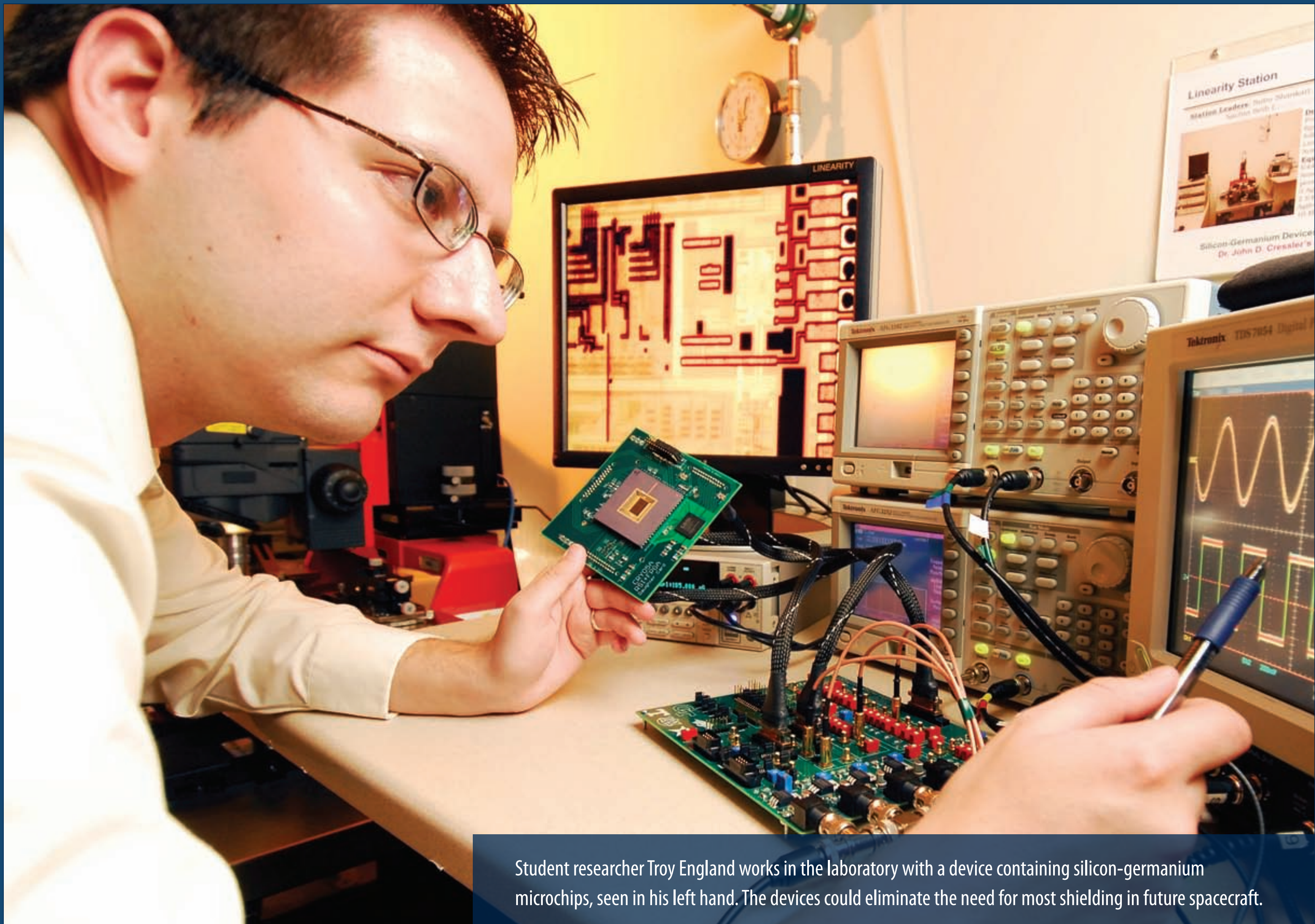
— John Cressler, professor in the School of Electrical and Computer Engineering



NASA space vehicles, such as this Mars Rover, must include protection for electronic equipment. Research led by Georgia Tech engineers examined the use of silicon-germanium materials able to withstand extreme temperature changes and radiation without conventional protection.

Image: NASA

Photo: Gary Meek



Student researcher Troy England works in the laboratory with a device containing silicon-germanium microchips, seen in his left hand. The devices could eliminate the need for most shielding in future spacecraft.

vices from radiation and temperature extremes, Keys explained. Designers must place most electronics in a protected, temperature-controlled central location and then connect them via long and heavy cables to sensors or other external devices.

By eliminating the need for most shielding and special cables, silicon-germanium technology helps reduce the single biggest problem in space launches: weight. Moreover, robust SiGe circuits can be placed wherever designers want, which helps eliminate data errors caused by impedance variations in lengthy wiring schemes.

"For instance, the Mars Exploration Rovers, which are no bigger than a golf cart, use several kilometers of cable that lead into a warm box," Keys said. "If we can move most of those electronics out to where the sensors are on the robot's extremities, that will reduce cabling, weight, complexity and energy use significantly."

A Collaborative Effort

NASA currently rates the new SiGe electronics at a technology readiness level of six, which means the circuits have been integrated into a subsystem and tested in a relevant environment. The next step, level seven, involves integrating the SiGe circuits into a vehicle for space flight testing. At level eight, a new technology is mature enough to be integrated into a full mission vehicle, and at level nine the technology is used regularly by missions.

Successful collaboration was an important part of the silicon-germanium team's effectiveness, Keys said. He remarked that he had "never seen such a diverse team work together so well."

Professor Alan Mantooth, who led a large University of Arkansas contingent involved in modeling and circuit-design tasks, agreed. He called the project "the most successful collaboration that I've been a part of."

Mantooth termed the extreme-electronics project highly useful in the education mission of the participating universities. He noted that a total of 82 students from six universities worked on the project over five years.

Richard W. Berger, a BAE Systems senior systems architect who collaborated on the project, also praised the student contributions.

"To be working both in analog and digital, miniaturizing, and developing extreme-temperature and radiation tolerance all at the same time – that's not what you'd call the average student design project," Berger said.

Photo: Gary Meek

Miniaturizing an Architecture

BAE Systems' contribution to the project included providing the basic architecture for the remote electronics unit (REU) sensor interface prototype developed by the team. That architecture came from a previous electronics generation: the now-cancelled Lockheed Martin X-33 Spaceplane initially designed in the 1990s.

In the original X-33 design, Berger explained, each sensor interface used an assortment of sizeable analog parts for the front-end signal-receiving section. That section was supported by a digital microprocessor, memory chips and an optical bus interface – all housed in a protective five-pound box.

The extreme environments team transformed the bulky X-33 design into a miniaturized sensor interface, utilizing silicon germanium. The resulting SiGe device weighs about 200 grams and requires no temperature or radiation shielding. Large numbers of these robust, lightweight REU units could be mounted on spacecraft or data-gathering devices close to sensors, reducing size, weight, power and reliability issues.

Berger said that BAE Systems is interested in manufacturing a sensor interface device based on the extreme environment team's discoveries.

Other space-oriented companies are also pursuing the new silicon-germanium technology, Cressler said. NASA, he explained, wants the intellectual-property barriers to the technology to be low so that it can be used widely.

"The idea is to make this infrastructure available to all interested parties," he said. "That way it could be used for any electronics assembly – an instrument, a spacecraft, an orbital platform, lunar-surface applications, Titan missions – wherever it can be helpful. In fact, the process of defining such an NASA mission-insertion roadmap is currently in progress." rh

Watch a video on this project: http://bit.ly/ofhdgl

Professor John Cressler (standing) and student researcher Eleazar Kenyon examine a functional prototype developed for NASA using silicon-germanium microchips.

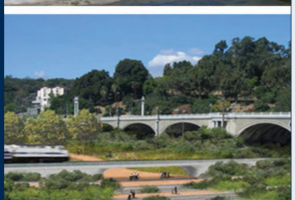
A program called "Red Fields to Green Fields" has proposed a solution for the thousands of distressed commercial buildings nationwide: demolishing or repositioning the structures and replacing them with conservation land, urban farms, infrastructure improvements or other green space. These "green" uses could attract economic development when the economy recovers.

Blight to Beauty:

"Red Fields to Green Fields" Plan Proposes Converting Distressed Properties to Parks

By Abby Robinson

Images: "Red Fields to Green Fields"



(Above) An artist's rendering (bottom) of how an area of riverfront filled with concrete (top) could be converted into an attractive green space through programs like "Red Fields to Green Fields."
(Below) Rendering of an area around the Los Angeles River.

With thousands of commercial buildings in foreclosure and many others in disrepair, cities around the country are looking for ways to rescue the properties and eliminate community blight. A program called "Red Fields to Green Fields" proposes acquiring these abandoned and underutilized properties, demolishing or repositioning them, and replacing them with conservation land, urban farms, infrastructure improvements or other green space. These "green" uses could attract economic development when the economy recovers.

"Red field properties have negative value civically, environmentally and economically. Converting this underused commercial real estate to green space that could be built on again when the economy improves would be transformational," said Kevin Caravati, a senior research scientist at the Georgia Tech Research Institute (GTRI). "The conversion would create demolition, design and landscaping jobs, and stabilize housing and property values, around the distressed properties."

With support from the Speedwell Foundation, Georgia Tech has helped 11 U.S. cities assess the supply of distressed commercial real estate in their communities and determine the best approaches for turning some of that property into green space. In June, representatives from Detroit, Houston, Los Angeles, Phoenix and Hilton Head Island revealed their cities' "Red Fields to Green Fields" study results. Altogether, the five cities' plans could create 20,000 acres of new parkland.

For the "Red Fields to Green Fields" project, each city asked the same question: "What if we invest a few billion dollars in our city to convert red fields to green fields?"

To answer the question, Georgia Tech researchers helped each city utilize financial models used by the U.S. Department of the Interior and data reported by the Federal Reserve Bank to quantify the economic, health, social, policy and engineering impacts of turning red fields into green fields. They also incorporated data from city master plans, green space plans, transportation reports, urban infrastructure redevelopment programs and geographic information system databases. The reports were written in collaboration with the City Parks Alliance and 14 universities, local government agencies and stakeholders.

While each city had a different story, the answer was always the same. Thousands of acres of underutilized residential and commercial real estate assets could be rescued and restored through public park planning to enhance the city's economic, environmental and physical health.

"This type of conversion would spur business activity, create jobs and address the real estate problem at its source – oversupply," said Michael Messner of the New Jersey-based Speedwell Foundation. "And its economic effect would be multiplied with increased infrastructure spending, leverage from unlocking banks' reserves, and real estate owner's willingness to spend again knowing their real estate values have stabilized."

The five new city reports add to reports published last year for six other cities – Atlanta, Denver, Philadelphia, Cleveland, Miami and Wilmington, Del.

Since publishing its report, Denver, in collaboration with the Trust for Public Land and private donors, started acquiring red field sites along the South Platte River Corridor. It is estimated that these investments and implementation of a robust program in Denver could remove more than 6,000 acres of distressed real estate from the market, creating an almost $4 billion impact.

"This Red Fields to Green Fields concept has the potential to dramatically multiply the economic development power of parks," said Chris Nevitt, Denver City Council president. "It addresses the most persistent, malignant drag on our economy, that is, the capital that is locked up in unproductive, vacant real estate projects."

During the past year, Miami also began executing its proposal, which tied into its city master plan. The city is working to acquire land through public-private partnerships. Miami's report stated that the tax base could be increased by an estimated $59 million per year by converting 312 acres of non-performing real estate to transit-oriented development. In addition, linking Everglades National Park and Biscayne Bay National Park could create 1,625 acres of additional parkland.

During the next year, the Georgia Tech research team will focus its efforts on helping the 11 cities implement the plans in their reports.

Other researchers involved in the "Red Fields to Green Fields" program include Joseph Hughes, chair of the Georgia Tech School of Civil and Environmental Engineering; Joseph Goodman and Carolyn Knabel, graduate students in the Georgia Tech College of Architecture; Cade Strippelhoff, a graduate student in the Georgia Tech School of Public Policy; and Erin Keller, an undergraduate student in the Wallace H. Coulter Department of Biomedical Engineering at Georgia Tech and Emory University. rh

CONTACT

Kevin Caravati
kevin.caravati@gtri.gatech.edu

"Converting this underused commercial real estate to green space that could be built on again when the economy improves would be transformational. The conversion would create demolition, design and landscaping jobs, and stabilize housing and property values, around the distressed properties."

— Kevin Caravati, senior research scientist at the Georgia Tech Research Institute

Atlanta's Piedmont Park is an example of green space that enhances a city's economic, environmental and physical health.

Photo: Georgia Department of Economic Development

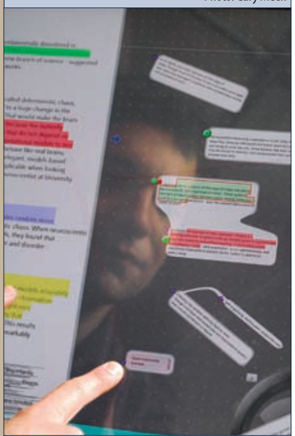
Researchers have developed software that facilitates an innovative approach to active reading. Taking advantage of touch-screen tablet computers, LiquidText software enables active readers to interact with documents using finger motions, significantly improving the reading experience.

Making Reading Better:

LiquidText Software Supports Active Reading Through Fingertip Manipulation of Text

By Abby Robinson

Photo: Gary Meek



Using LiquidText software, comments can be pulled off, rearranged and grouped with other items while maintaining a persistent link back to the content to which they refer.

Many reading tasks require individuals to not only read a document, but also to understand, learn from and retain the information in it. For this type of reading, people frequently do what experts call active reading, which involves highlighting, outlining and taking notes on the text.

Georgia Tech researchers have developed software that facilitates an innovative approach to active reading. Taking advantage of touch-screen tablet computers, LiquidText software enables active readers to interact with documents using finger motions, significantly improving the reading experience.

"Most computer-based active-reading software seeks to replicate the experience of paper, but paper has limitations, being in many ways inflexible," said Georgia Tech graduate student Craig Tashman. "LiquidText offers readers a fluid-like representation of text so that users can restructure, revisualize and rearrange content to suit their needs."

LiquidText was developed by Tashman and Keith Edwards, an associate professor in the Georgia Tech School of Interactive Computing. The software can run on any Windows 7 touch-screen computer.

Details on LiquidText were presented in May 2011 at the Association for Computing Machinery's annual Conference on Human Factors in Computing Systems (CHI) in Vancouver, Canada. Development of LiquidText was supported by the National Science Foundation, Steelcase, Samsung and Dell.

Active reading demands more of the reading medium than simply advancing pages, Edwards noted. Active readers may need to create and find a variety of highlights and comments, and move rapidly among multiple sections of a document.

"With paper, it can be difficult to view disconnected parts of a document in parallel, annotation can be constraining, and its linear nature gives readers little flexibility for creating their own navigational structures," said Tashman.

LiquidText provides flexible control of the visual arrangement of content, including both original text and annotations. To do this, the software builds on common touch-screen fingertip gestures with a variety of novel single and multi-finger interactions. For example, to view two areas of a document at once, the user can pinch an area of text, collapse it and bring disparate text into proximity.

Active reading involves annotation, content extraction and fast, fluid navigation among multiple portions of a document. To accomplish these tasks, LiquidText integrates a traditional document reading space with a dedicated workspace area where the user can organize excerpts and annotations of a text – without losing the links back to their sources. In these spaces, the user can highlight text, comment about text, extract text, collapse text, bookmark text and magnify text.

For commenting, LiquidText breaks away from the traditional one-to-one mapping between content and comments. Comment objects can refer to any number of pieces of content across a document, or even multiple documents. Comments can be pulled off, rearranged and grouped with other items while maintaining a persistent link back to the content they refer to. To add a comment, users simply select the desired text and begin typing.

"The problem with paper and some software programs is that the comments must generally fit in the space of a small margin and can only be linked to a single page of text at a time," said Tashman. "LiquidText's more flexible notion of comments and large workspace area provide space for organizing and manipulating any comments or document excerpts the user may have created."

The ability to move within a document, search for text, turn a page or flip between locations to compare parts of a text is also important for active reading.

"In contrast to traditional document viewing software, in which users must create separate panes and scroll them individually, LiquidText's functionality lets a user view two or more document areas with just one action, parallelizing an otherwise serial task," explained Edwards.

Tashman currently is working with Georgia Tech's Enterprise Innovation Institute to form a startup company to commercialize the technology. A prize from the Georgia Tech Edison Fund and grants from the Georgia Research Alliance will help the new company that plans to introduce LiquidText to the public later this year.

This project is supported in part by the National Science Foundation (Award No. IIS-0705569). The content is solely the responsibility of the principal investigator and does not necessarily represent the official views of the NSF.

CONTACTS

Keith Edwards
keith@cc.gatech.edu

Craig Tashman
craig@cc.gatech.edu

"Most computer-based active-reading software seeks to replicate the experience of paper, but paper has limitations, being in many ways inflexible. LiquidText offers readers a fluid-like representation of text so that users can restructure, revisualize and rearrange content to suit their needs."

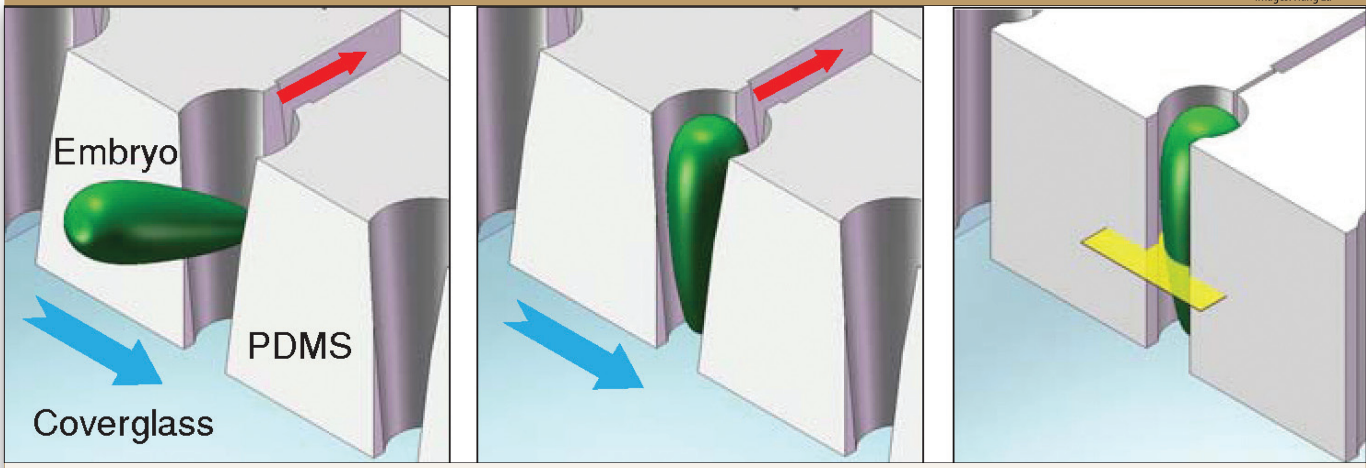
— Georgia Tech graduate student Craig Tashman

Graduate student Craig Tashman (left) and School of Interactive Computing associate professor Keith Edwards annotate and extract content from a document using software they developed called LiquidText.

Photo: Gary Meek

Microfluidic Device Automatically Orients Fly Embryos for Experiments

Images: Hang Lu



Schematic shows the embryo trapping process: (left) the cross-flow guides an embryo into the cylindrical trap; (middle) the flow around the embryo orients it vertically; (right) the trap contracts after loading is finished and secures the embryo inside the trap. The yellow plane represents the focal plane where images are obtained.

Researchers have developed a microfluidic device that automatically orients hundreds of fruit fly and other embryos to prepare them for research. The device could facilitate the study of such issues as how organisms develop their complex structures from single cells.

Scientists know that among an embryo's first major developments is the establishment of its dorsoventral axis, which runs from its back to its belly. Determining how this axis development unfolds requires the ability to simultaneously monitor large numbers of embryos with different genetic backgrounds at several time points.

"Collecting and analyzing the signaling and transcriptional patterns of the dorsoventral axis typically requires manual manipulation of individual embryos to stand them on their ends, making it difficult to conduct high-throughput experiments that can achieve statistically significant results," said Hang Lu, an associate professor in the Georgia Tech School of Chemical & Biomolecular Engineering.

To enable large-scale quantitative analyses of protein-positional information along the dorsoventral axis, Lu designed a microfluidic device that reliably orients several hundred embryos in just a few minutes.

Details of the device were published in the Feb. 2011 issue of the journal *Nature Methods*. This project was supported by the National Science Foundation, the National Institutes of Health, the Alfred P. Sloan Foundation and the DuPont Young Professor program.

Lu designed and fabricated the device with the help of Kwanghun Chung and Emily Gong, who worked on the project as Georgia Tech graduate and undergraduate students, respectively. Fabricated from polydimethylsiloxane (PDMS), the compact device is the size of a microscope slide and contains approximately 700 traps for embryos, which are shaped like grains of rice but smaller in size.

In operation, fluid flows through an "S"-shaped channel wide enough for embryos of any orientation to move easily through it. The fluid efficiently directs the embryos toward the traps, while sweeping out extra and improperly trapped embryos.

"Experimentally, we found on average 90 percent of the embryos became trapped in the device, which will be valuable for studies that only have a small number of embryos available," Lu explained.

When an embryo approaches an empty trap, it experiences non-uniform pressure and shear from the surrounding fluid. The resulting force flips the embryo vertically and inserts it into the cylindrical trap in an upright position, with its dorsoventral axis parallel to the ground. The embryo is then secured inside the trap, without any need for user intervention or control. The lock-in feature allows the device to be disconnected from the rest of the hardware and transported for imaging or storage with the embryos enclosed.

To demonstrate the device's capabilities, Lu collaborated with Stanislav Shvartsman, an associate professor in the Department of Chemical and Biological Engineering at Princeton University, and his graduate student Yoosik Kim. The Princeton researchers used the device to quantify gradients of signaling molecules called morphogens in fixed embryos and also used it to monitor nuclear divisions in live embryos.

This project was supported by the National Science Foundation (NSF) (Award No. DBI-0649833) and the National Institutes of Health (NIH) (Award No. R21NS058465). The content is solely the responsibility of the principal investigator and does not necessarily represent the official views of the NSF or NIH.

— Abby Robinson

Contact:
Hang Lu
hang.lu@gatech.edu

This photograph shows a penny next to the microfluidic device designed to automatically orient hundreds of embryos to prepare them for research.

Photo: Hang Lu

Study of Soil Effects from Earthquake Could Improve Building Design

Japan's March 11, 2011, earthquake was among the strongest ever recorded, and because it struck one of the world's most heavily instrumented seismic zones, this natural disaster is providing scientists with a treasure trove of data on rare magnitude 9 earthquakes. Among the new information is what is believed to be the first study of how a shock this powerful affects the rock and soil beneath the surface.

Analyzing data from multiple measurement stations, Georgia Tech scientists found that the quake weakened subsurface materials by as much as 70 percent. That nonlinear response from the top layer of the Earth's crust affected how movement deep beneath the surface was delivered to buildings, bridges and other structures.

Understanding how the soil responds to powerful earthquakes could be important to engineers and architects designing future buildings to withstand the level of acceleration measured in this quake. The information also will help seismologists develop new models to predict the effects of these rare and extremely powerful events.

"The degree of nonlinearity in the soil strength was among the largest ever observed," said Zhigang Peng, an associate professor in Georgia Tech's School of Earth and Atmospheric Sciences. "This is perhaps not too surprising because the ground shaking generated by this earthquake – acceleration as much as three times the Earth's gravity – is also among the highest ever observed."

The findings were reported in a special issue of the journal *Earth, Planets and Space* (EPS). The research was sponsored by the National Science Foundation (NSF) and by the Southern California Earthquake Center (SCEC).

Peng and graduate student Chunquan Wu were among the first scientists to examine data recorded by the seismometers that are part of the Japanese Strong Motion Network KIK-Net. The stations have accelerometers both on the surface and in boreholes located on bedrock far beneath it. The researchers chose to study data from six stations that have strong velocity contrasts between the surface soil layers and the underlying bedrock.

"In this study, we were trying to understand the relationship between soil nonlinearity and peak ground acceleration (PGA), which is a measure of the ground shaking," said Wu. "We want to understand what parameters control this kind of response."

By comparing data on the acceleration of motion from sensors on the bedrock to comparable information from surface sensors, they were able to study how the properties of the soil changed in response to the shaking. The researchers computed the spectral ratios of each pair of station measurements, and then used the ratios to track the temporal changes in the soil response at various sites at different levels of peak ground acceleration.

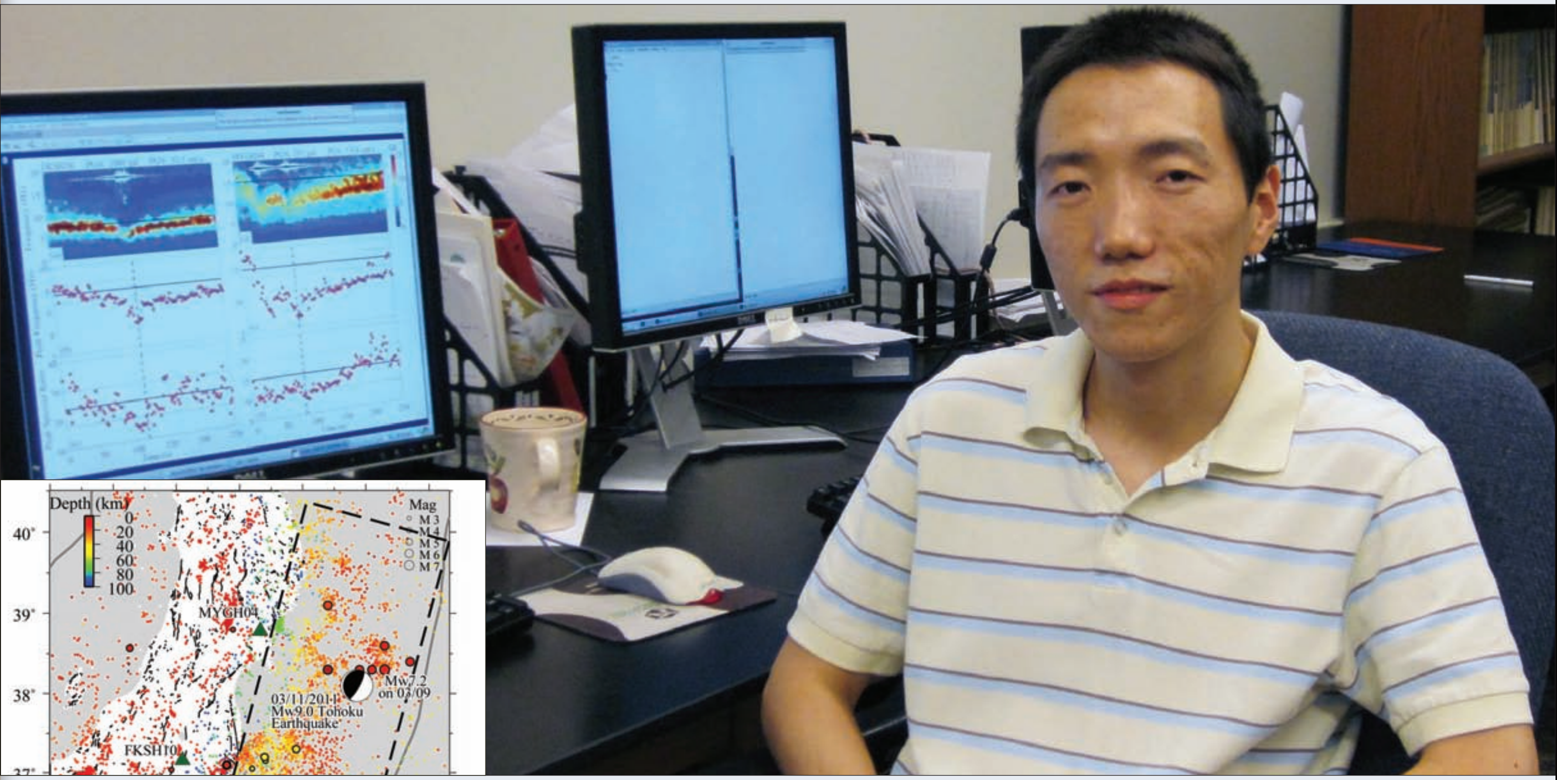
"The shear modulus of the soil was reduced as much as 70 percent during the strongest shaking," Wu explained. "Typically, near the surface you have soil and several layers of sedimentary rock. Below that, you have bedrock, which is much harder than the surface material. When seismic waves propagate, the top layers of soil can amplify them."

Nonlinear response from soils is not unusual, though it varies depending on composition. The shallow layers of the Earth's upper crust can be complex, composed of varying types of soil, clay particles, gravel and larger rock layered in sediments. Similar but smaller effects have been seen in other earthquake-prone areas such as California and Turkey, Wu said.

— John Toon

Contact:
Zhigang Peng
zpeng@gatech.edu

Images: Chunquan Wu

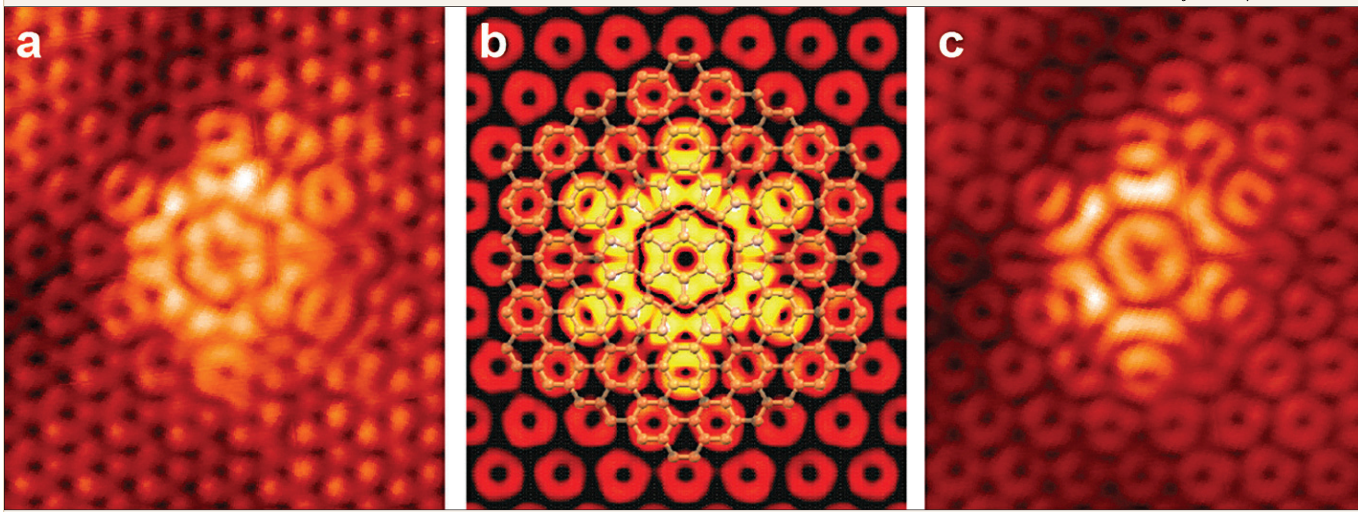


Chunquan Wu, a graduate student in the School of Earth and Atmospheric Sciences, is shown with data from the March 11 Japan Earthquake. The inset shows the area studied.

RESEARCH NOTES

Flower-Like Defects May Help Graphene Respond to Stress

Images: Eric Cockayne, NIST



Flower-like defects in graphene are shown in these images (a and c) produced by a scanning tunneling microscope. Image b was created by a computer model. Understanding these defects could be important to future uses of graphene.

Beyond its ability to conduct electrons almost without resistance, the nanomaterial graphene also has amazing mechanical properties, including high strength that could one day make it useful in lightweight, robust structures. But this material is not without flaws, including a family of flower-like defects that could detract from its electronic and mechanical properties.

In an article published in the journal *Physical Review B*, researchers at Georgia Tech and the National Institute of Standards and Technology (NIST) have described a family of seven potential defect structures that may appear in sheets of graphene. They imaged examples of the lowest-energy defect in the family.

The defects may arise to help relieve mechanical stress in graphene's carbon-atom honeycomb structure by allowing atoms to spread out and occupy slightly more space. Such stress may develop during the growth of graphene or by stretching the graphene sheet.

"For an engineer interested in the mechanical properties of graphene to create atom-thick membranes, for instance, it would be very important to understand these kinds of properties, which could give rise to plastic deformation of the material," said Phillip First, a co-author of the article and a professor in the Georgia Tech School of Physics. "For instance, it may be that these defects are just one part of the kinetic pathway to failure for a strained sheet of graphene."

For electronic applications, the defects could deflect electrons and cause backscattering that would increase the resistance of the material – like a rock in a stream slows the flow of water. However, First says improved growth techniques developed since the defect study began may eliminate that concern.

"With the growth techniques that have now been developed using silicon carbide, we typically do not see these defects," he noted.

Defects can appear due to the movement of carbon atoms at high temperatures, explained NIST Fellow Joseph Stroscio. Rearrangements of graphene that require the least amount of energy involve switching from the standard six-member carbon rings to structures containing either five or seven atoms. The NIST researchers have discovered that stringing five- and seven-member rings together in closed loops creates a new type of defect or grain boundary loop in the honeycomb lattice.

According to NIST researcher Eric Cockayne, the fabrication process plays a big role in creating the defects.

"As the graphene forms under high heat, sections of the lattice can come loose and rotate," he said. "As the graphene cools, these rotated sections link back up with the lattice, but in an irregular way. It's almost as if patches of the graphene were cut out with scissors, turned clockwise, and made to fit back into the same place. Only it really doesn't fit, which is why we get these flowers."

Georgia Tech contributions to this work were funded by the Semiconductor Research Corporation (NRI-INDEX) and by the National Science Foundation through the Georgia Tech Materials Research Science and Engineering Center (MRSEC) under grants DMR-0804908 and DMR-0820382.

— John Toon

Contact:
Phillip First
phillip.first@physics.gatech.edu

GTRI Leads $10 Million Homeland Open Security Technology Program

The U.S. Department of Homeland Security (DHS) Science and Technology (S&T) Directorate has selected the Georgia Tech Research Institute (GTRI) to lead implementation efforts for the five-year, $10 million Homeland Open Security Technology (HOST) program. The HOST program will investigate open source and open cyber security methods, models and technologies, and identify viable and sustainable approaches that support national cyber security objectives.

"The strategic objective of the HOST program is to lead efforts of discovery and collaboration, seeding development in open source software and practices that produce a measurable impact for government cyber security systems," said Joshua L. Davis, associate division head at GTRI's Cyber Technology and Information Security Laboratory and principal investigator for the HOST program. "The collaborative nature of open source and open technologies provides unique technical and economic value and opportunities for government users."

Open technologies are not a panacea for all challenges, Davis added. HOST will reach out to government, industry, academic and open source community representatives to learn where and how open technologies have been successfully adopted within public and private systems, and where the challenges still remain.

"As we go, we are sharing this information across government agencies and helping to build networks of users, service and support providers, and policy influencers, and providing a venue to enable them to discuss, share and learn from collective experiences," Davis said. "The collective is what gives open source its strength. We are simply applying this successful strategy to address government cyber security challenges."

GTRI is leading HOST efforts in conjunction with the Open Technology Research Consortium (OTRC), a collaborative network of leading academic research institutions, industry partners and open source community organizations that work to promote the advancement of open source software adoption within government agencies. OTRC members participating in the HOST program include the Georgia Tech Research Institute, University of Texas at Austin, the Open Information Security Foundation and the Open Source Software Institute.

— Rick Robinson

Contact:
Joshua Davis
joshua.davis@gtri.gatech.edu

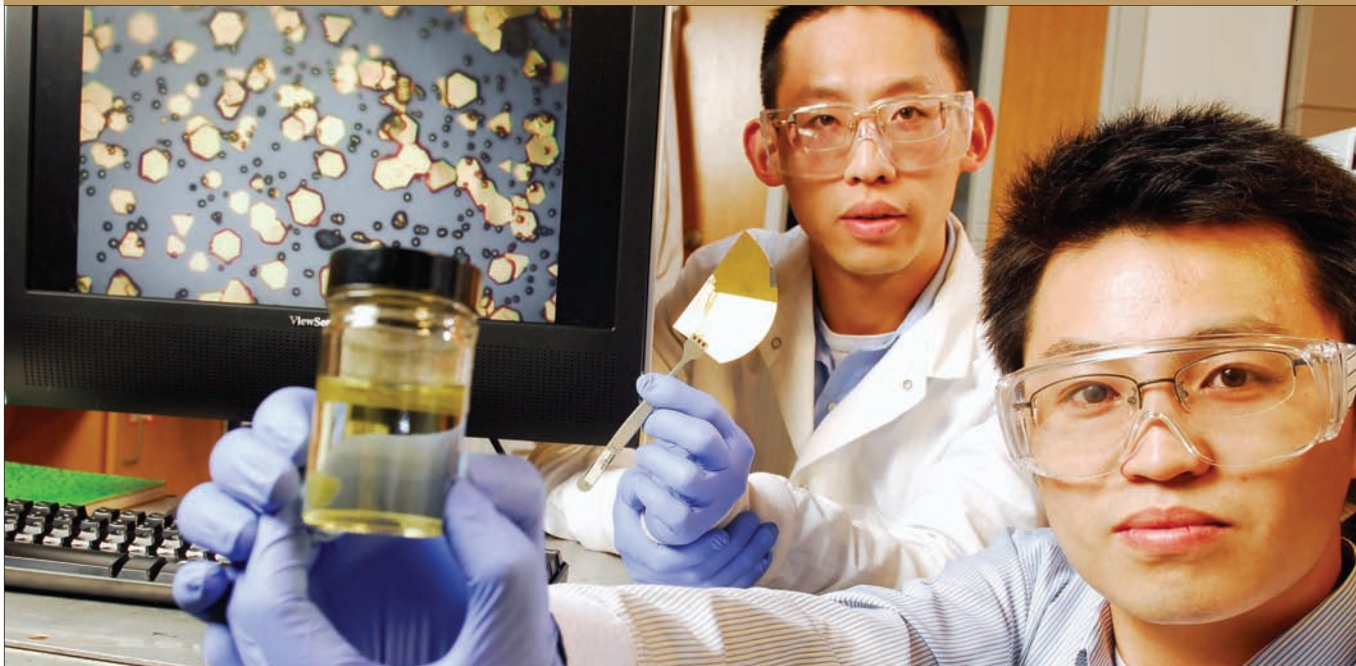
Photo: Gary Meek

Joshua Davis will serve as principal investigator for a new U.S. Department of Homeland Security program that will investigate open source and open cyber security methods, models and technologies, and identify viable and sustainable approaches that support national cyber security objectives.

RESEARCH NOTES

New Solvent System May Improve Recycling of Catalysts

Photo: Gary Meek



Researcher Rong-Wei Zhang holds a gold/organic aqua regia solution while colleague Wei Lin holds a silicon substrate coated with 200-nanometer gold. The image on the monitor shows gold recovered from the solution using calcinations.

Noble metals such as platinum and palladium are becoming increasingly important because of growth in environmentally friendly applications such as fuel cells. To help meet the need for these materials, manufacturers are looking for more efficient recycling processes.

Existing recycling processes use a combination of two inorganic acids known as "aqua regia" to dissolve noble metals, a class of materials that includes platinum, palladium, gold and silver. But because the metals are often dissolved together, impurities introduced in the recycling process may harm the efficiency of catalysts produced from the recycled materials.

Georgia Tech researchers have developed a new organic solvent process that may help address the problem – and open up new possibilities for using these metals in cancer therapeutics, microelectronics and other applications.

The new solvent system uses a combination of two chemicals – thionyl chloride and a variety of organic reagents such as pyridine, N,N-dimethylformamide (DMF), pyrimidine or imidazole. The concentrations can be adjusted to preferentially dissolve gold or palladium. And, more importantly, no combination of the organic chemicals dissolves platinum. This ability to preferentially dissolve noble metals creates a customized system that provides a high level of control over the process.

"We need to be able to selectively dissolve these noble metals to ensure their purity in a variety of important applications," said C.P. Wong, a Regents professor in the Georgia Tech School of Materials Science and Engineering. "Though we don't fully understand how it works yet, we believe this system opens a lot of new possibilities for using these metals."

So far, the researchers have demonstrated that the solvent system can selectively dissolve gold and palladium from a mixture of gold, palladium and platinum. They have also used it to remove gold from a mixture of gold and palladium.

Beyond recycling, the new solvent system could also provide new ways of producing nanometer-scale cancer chemotherapy agents that involve these metals. And the new solvent approach could have important implications for the electronics industry, which uses noble metals that must often be removed after specific processing steps. Beyond selectivity, the new approach also offers other advantages for electronics manufacturing: no potentially harmful contamination is left behind and processing is done under mild conditions.

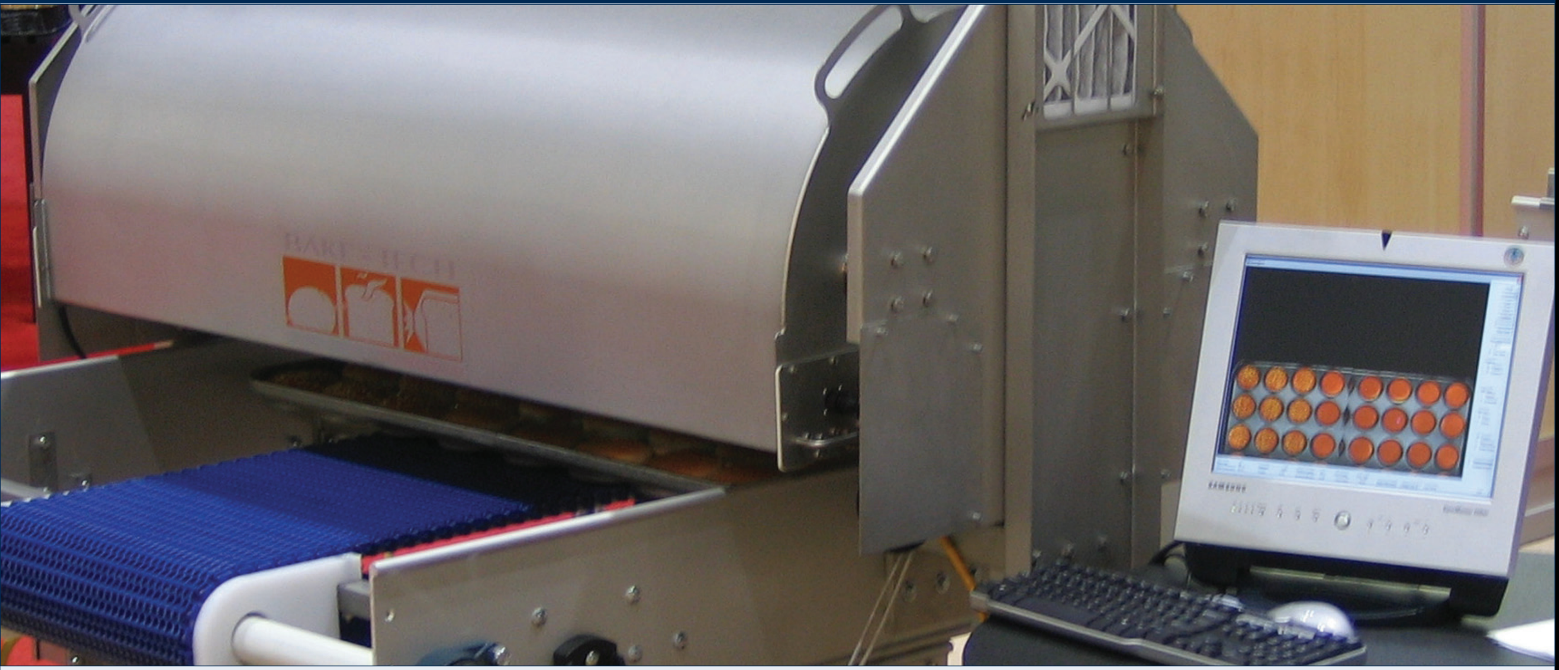
"In semiconductor production, people want to avoid having a metal catalyst remaining in devices, but in many cases, they cannot use existing water-based processes because these can damage the semiconductor oxides and introduce contamination with free ions in the aqueous solution," explained Wei Lin, a graduate research assistant in Wong's laboratory. "Use of this organic system avoids the problem of moisture."

In addition to those already mentioned, the research team included Rong-Wei Zhang, Seung-Soon Jang and Jung-Il Hong, all from the School of Materials Science and Engineering at Georgia Tech.

— John Toon

Contact:
C.P. Wong
cp.wong@mse.gatech.edu

Imaging System Controls Baking to Produce Perfect Buns



The Georgia Tech Research Institute (GTRI) has developed a production-line system that automatically inspects the quality of sandwich buns exiting the oven and adjusts oven temperatures if it detects unacceptable buns.

The Georgia Tech Research Institute (GTRI) may possess the secret to baking perfect buns every time. Its researchers have developed a production-line system that automatically inspects the quality of sandwich buns exiting the oven and adjusts oven temperatures if it detects unacceptable buns.

"We have closed the loop between the quality inspection of buns and the oven controls to meet the specifications required by food service and fast-food customers," said GTRI senior research engineer Douglas Britton. "By creating a more accurate, uniform and faster assessment process, we are able to minimize waste and lost product."

During existing inspection processes, workers remove a sample of buns each hour to inspect their color. Based on this assessment, they manually adjust the oven temperature if the buns appear too light or too dark. But with more than 1,000 buns leaving a bakery production line every minute, there is a great need for automated control to make more rapid corrections to produce buns of consistent color, size, shape and seed coverage.

"Automated control over the baking process is necessary to produce a consistent product through batch changes, shift changes, daily and seasonal temperature and humidity changes, and variations in ingredients," added Britton.

Working with baking company Flowers Foods, headquartered in Thomasville, Ga., and Baking Technology Systems (BakeTech), a baking equipment manufacturer in Tucker, Ga., Britton and GTRI research scientist Colin Usher have tested their industrial-quality prototype system. Made of stainless steel, the system is dust- and water-resistant, and mounts to existing conveyor belts as wide as 50 inches.

Britton and Usher tested the system in a Flowers Foods bakery for a year, running it regularly for hour-long intervals. During this testing phase, the system successfully inspected a variety of buns, including seeded buns, unseeded buns, different size buns and different top-bun shapes. For the past year, the system has been in full-operational mode in the bakery.

"Without the imaging system, it would be impossible for an operator to respond quickly enough to make the correct changes to the oven to improve the target color of the product," said Stephen Smith, BakeTech's vice president and director of engineering.

As fresh-baked buns move along Flowers' production line, a digital camera captures an image of them. Items not measuring up in terms of color are identified by imaging software, and the color information is automatically sent to the oven controllers, which adjust the oven temperature to correct the issue.

"Our system reduces the time between noticing a problem and fixing it," Usher explained. "The window for correction is short, though, because an entire batch may only take eight to 12 minutes to bake."

Initial funding for this project was provided by Georgia's Traditional Industries Program for Food Processing, which is managed through the Food Processing Advisory Council (FoodPAC).

— Abby Robinson

Contacts:

Douglas Britton
douglas.britton@gtri.gatech.edu

Colin Usher
colin.usher@gtri.gatech.edu

Georgia Institute of Technology

Research News & Publications Office
75 Fifth Street, N.W., Suite 100
Atlanta, GA 30308-1021 USA

CHANGE SERVICE REQUESTED

Nonprofit
Organization
US Postage
PAID
Atlanta, GA 30332
Permit No. 587

Research Horizons
Volume 28, Number 2 • Summer/Fall 2011


Georgia Tech Research Newsletter

Restoring Reefs: Study Underway in Aquarius Underwater Laboratory May Help Manage Seaweed-Eating Fish that Protect Coral Reefs

September 15, 2011 -- A team of researchers from the Georgia Institute of Technology is using the Aquarius underwater laboratory off the coast of Florida to study how the diversity of seaweed-eating fish affects endangered coral reefs. The research mission, which began Sept. 13, may provide new information to help scientists protect and even restore damaged coral reefs in the Caribbean.

Cybersecurity Companies Boost Atlanta's Industry Role

Winter/Spring 2011 Research Horizons Magazine -- Georgia Tech cybersecurity faculty members are helping

Research Horizons

Research Horizons is published three times per year to communicate the results of research conducted at the Georgia Institute of Technology. PDFs of past issues, along with top feature stories from past issues, are available.

Connect With Us

SIGN UP FOR THE GEORGIA TECH RESEARCH E-NEWSLETTER

Georgia Tech's Research News and Publications Office now offers a monthly e-newsletter that will make keeping track of our research discoveries easier than ever.

To sign up for the e-newsletter, visit **http://bit.ly/nUlrqL** or scan the QR code below.

Research Horizons is printed on paper containing 10 percent post-consumer fiber.

Georgia Tech Administration
Stephen Cross, Executive Vice President for Research
Stephen Fleming, Vice President and Executive Director of the Georgia Tech Enterprise Innovation Institute
Robert McGrath, Vice President and Director of the Georgia Tech Research Institute