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## Cartilage Monitoring

*High-resolution imaging with contrast agent yields promise in research of osteoarthritis.*

An innovative combination of existing technologies shows promise for noninvasive, high-resolution imaging of cartilage in research on the progression and treatment of the common degenerative disease osteoarthritis.

Microcomputed tomography (microCT) — which yields three-dimensional X-ray images with a resolution 100 times higher than clinical CT scans — is commonly used to image bone for osteoporosis research, but has not been useful for imaging soft biological tissues such as cartilage. These tissues simply don't interfere with the microCT's X-rays as they pass through a sample, and therefore don't show up on scans.

But by combining microCT with an X-ray-absorbing contrast agent that has a negative charge, researchers at the Georgia Institute of Technology were able to

image the distribution of negatively charged molecules called proteoglycans (PGs). These molecules are critical to the proper functioning of cartilage.

"By detecting PG content and distribution, the technique reveals information about both the thickness and composition of the cartilage — important factors for monitoring the progression and treatment of osteoarthritis," says Marc Levenston, formerly an associate professor in Georgia Tech's George W. Woodruff School of Mechanical Engineering and now at Stanford University.

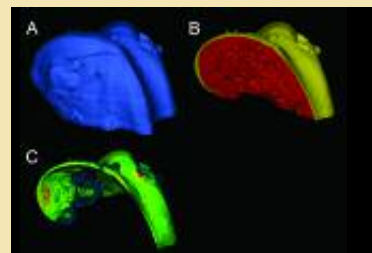
He and Professor Robert Guldberg, also in the School of Mechanical Engineering, collaborated to establish and validate the principle of the technique, dubbed Equilibrium Partitioning of an Ionic Contrast agent-microCT, or EPIC-microCT. Then they applied the technique *in vitro*

to monitor the degradation of bovine cartilage cores and to visualize the thin layer of cartilage in an intact rabbit knee.

"This technique will allow pharmaceutical researchers to obtain more detailed information about the effects of new drugs and other treatment strategies for treating osteoarthritis," Levenston says.

A report on the research was published in the Dec. 19, 2006 issue of the journal *Proceedings of the National Academy of Sciences*. The National Science Foundation, National Institute of Arthritis and Musculoskeletal and Skin Disorders, and the Arthritis Foundation funded the work.

Experiments conducted by Ph.D. student Ashley Palmer established the principles and protocol of EPIC-microCT. Researchers first immersed cartilage samples in the contrast agent solution and waited for the agent to diffuse into the tissue. Tissue with fewer negatively charged PGs absorbed more of the negatively charged



ABOVE: A new cartilage-imaging technique called EPIC-microCT yields pictures of (A) an intact rabbit knee; (B) a segmented rabbit knee with cartilage (gold) isolated from bone (red); and (C) a topographical map illustrating the range of cartilage-layer thickness in the rabbit knee.

contrast agent, and tissue with a higher PG concentration repelled it.

Researchers then used EPIC-microCT to detect the concentrations of the contrast agent, which allowed them to calculate the amount of PGs in different parts of the cartilage. Because degrading cartilage loses PGs over time, researchers could monitor the progression of tissue

**RIGHT:** Georgia Tech Ph.D. student Ashley Palmer conducted experiments to validate a new cartilage-imaging technique developed in the Georgia Tech School of Mechanical Engineering. On the computer screen in the foreground is a thickness "map" of cartilage from a rabbit knee generated using software associated with the new imaging technique called EPIC-microCT. On the other screen is an image showing results of EPIC-microCT scans on bovine cartilage samples at various stages of degradation.

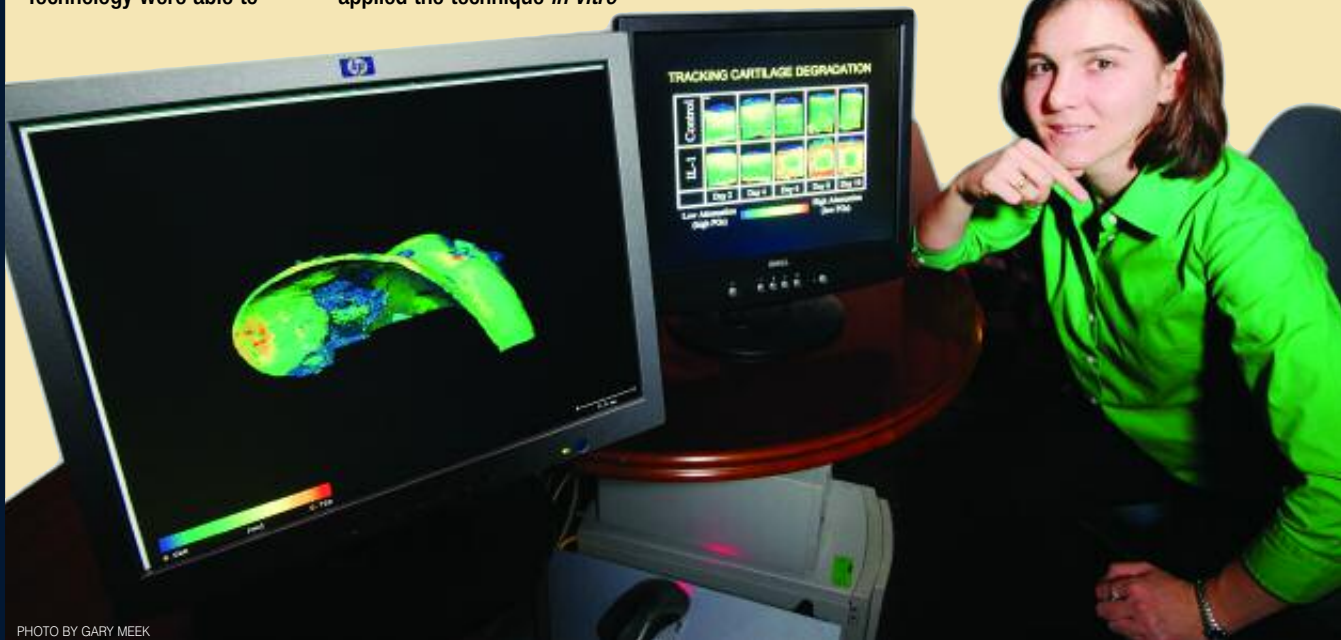


PHOTO BY GARY MEEK

changes. In addition, differences in the X-ray signal of cartilage and bone allowed researchers to isolate the cartilage layer on a rabbit joint and determine its thickness, indicating that this technique also can be used to measure tissue thinning during disease progression.

In follow-on research funded by a new, two-year grant from the National Institutes of Health, the researchers will gather additional quantitative data and use the technique to examine the very thin cartilage of rat knee joints. Researchers will nondestructively evaluate osteoarthritis progression and then attempt to use this approach to monitor cartilage changes over time *in vivo*, or inside the same live animals.

“Ultimately, if we can monitor cartilage changes with good resolution and do it with little or no invasion of the tissue in live animals, then we can track osteoarthritis progression and the effects of drug therapy or other treatments over time,” Guldberg says.

— Jane M. Sanders

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Read more at: [gtresearchnews.gatech.edu/newsrelease/cartilage-imaging.html](http://gtresearchnews.gatech.edu/newsrelease/cartilage-imaging.html)

## Enemy Detection

A new sensor that measures the motion created by sound waves under water could allow the U.S. Navy to develop compact arrays to detect the presence of enemy submarines. These new arrays would detect quiet underwater targets, while also providing unambiguous directional information.

Using optical fibers, researchers at the Georgia Institute of Technology have developed a sensor that detects the direction from which a sound is coming under water. This directional component is an important improvement over the current technology, researchers say.

“Detecting quiet sounds under water can be very difficult,” says Francois Guillot, a research engineer in Georgia Tech’s George W. Woodruff School of Mechanical Engineering. “But our sensor detects small sounds over the noise of the ocean and also provides directional information.”

The sensor uses a mechanism inspired by how fish hear under water. Inside a fish’s ear, there are thousands of tiny hairs that move when a sound wave passes through the fish. These hairs then communicate with nerves allowing fish to hear under water. Because fish excel at detecting sound so they don’t get eaten, the Georgia Tech

researchers chose the fish hearing system as their model.

In the field of underwater acoustics, there is always a need to develop more sophisticated sensors, researchers say. The Navy currently tows long lines of hydrophones to listen to sound under water — much like a microphone listens to sound in the air. A hydrophone measures the pressure change associated with the propagation of a sound wave. It converts acoustic energy into electrical energy and is used in passive underwater systems to listen only. One hydrophone identifies a sound nearby, and multiple hydrophones can help tell the direction from which it’s coming. But directional ambiguity exists. A line array of hydrophones cannot tell if the sound is coming from the left or right.

Guillot and collaborators David Trivett, a principal research scientist, and Peter Rogers, a professor — both in the School of Mechanical Engineering — have developed a more compact, more sensitive sound detector that can provide unambiguous directional information. In addition, the sensor can be modified to measure the water deformation, known as shear, associated with a sound wave — a quantity typically difficult to measure because it requires very sensitive instruments. This new sensor shows promise that it can be successfully modified

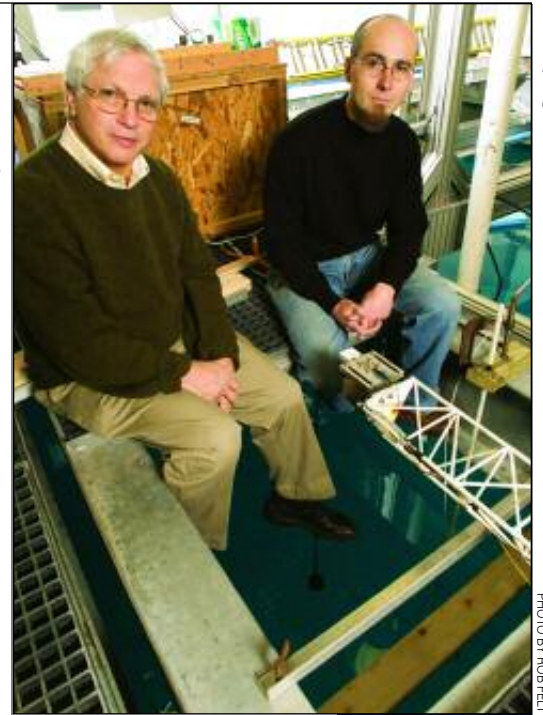


PHOTO BY ROB FELT

to detect this acoustic shear, which will enhance the directional information, the researchers say.

The research has been supported by a grant from Mike Traweek at the Office of Naval Research.

— Abby Vogel

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Read more at: [gtresearchnews.gatech.edu/newsrelease/underwater\\_sensor.htm](http://gtresearchnews.gatech.edu/newsrelease/underwater_sensor.htm)

**ABOVE:** Georgia Tech researchers Peter Rogers, left, and Francois Guillot are part of a team that developed a new sensor that measures the motion created by sound waves under water. It could help the U.S. Navy detect the presence of enemy submarines.



PHOTO BY ROB FELT

Using optical fibers, the sensor, above, detects the direction from which a sound is coming under water — an important improvement over current technology.

# RESEARCH NOTES

## Providing Secure Monitoring

A new shipping container security device in development by the Georgia Tech Research Institute could make U.S. ports less vulnerable to terrorist activities.

Containers equipped with the new devices will be continuously monitored for unauthorized attempts to open the container doors. The devices use a novel sensing technique. The system will communicate container information remotely to port authorities, providing a log of door activity and an alarm if an event occurs that requires

the device is to automatically detect the opening, closing and/or removal of container doors. A key feature of the sensing technique is a design that prevents tampering with or removal of the device from the container without an alarm being generated. This will provide a significant upgrade over current door security methods that rely on seals, which can easily be defeated, and will fix a major vulnerability in existing port security protocols.

Engineers are designing the system to monitor 20- and 40-foot “dry box” (non-refrigerated) containers. They are drawing upon GTRI’s expertise in integrated sensor systems development, including another DHS-sponsored project to develop concepts for an Advanced Container Security Device that was completed in October 2005.

Working with Bennett on this phase of the project are Terence Haran, Chris James, Tim Strike, Dave Fentem, Ben Brackett and Jeff Jo. Work on the security device is expected to be completed by summer 2007.

— Jane M. Sanders

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PHOTO BY GARY MEEK



Researchers, left to right, Chris James, Tom Michaels, Terence Haran, Gisele Bennett, and Jennifer Michaels are part of the original team developing an improved security device for shipping containers that could make U.S. ports less vulnerable to terrorist activities.

## A New Class of Electronic Components

Researchers have taken advantage of the unique coupled semiconducting and piezoelectric properties of zinc oxide nanowires to create a new class of electronic components and devices that could provide the foundation for a broad range of new applications.

So far, the researchers have demonstrated field-effect transistors, diodes, sensors — and current-producing nanogenerators — that operate by bending zinc oxide nanowires and nanobelts. The new components take advantage of the relationship between the mechanical and electronic coupled behavior of piezoelectric nanomaterials, a

mechanism dubbed “nano-piezotronics™” by the researchers.

“Nano-piezotronics uses the coupling of piezoelectric and semiconducting properties to fabricate novel electronic components,” says Zhong Lin Wang, a Regents Professor in the School of Materials Science and Engineering at the Georgia Institute of Technology. “These devices could provide the fundamental building blocks that would allow us to create a new area of electronics.”

For example, in a nano-piezotronic transistor, bending a one-dimensional zinc oxide nanostructure alters the distribution of electrical charges, providing control over the current flowing through it. By measuring changes in current flow through them,

(Continued on page 45)

PHOTO COURTESY GA. DEPT. ECONOMIC DEVELOPMENT



ABOVE: New remote security devices developed, in part, at the Georgia Tech Research Institute could improve security for shipping containers like these.

immediate attention.

“The system is intended to improve port security by monitoring improper access to the container,” says lead researcher Gisele Bennett, director of the Georgia Tech Research Institute (GTRI) Electro-Optical Systems Laboratory. “We need the ability to automatically detect unauthorized openings of container doors to prevent the potential introduction of illicit materials.”

In the research project, which is funded by the U.S. Department of Homeland Security (DHS), the function of

# Deadly Wave

*Researchers learn from analyses of rare tsunami earthquake that devastated Java in summer 2006.*



PHOTO BY NIKOS KALGERIS

“The violent tsunami impact on Nusa Kambangan ... shredded an entire forest and caused massive beach erosion of more than a meter vertically,” Fritz says. “The violent impact extended several miles beyond the area of island coastline we visited, but the rest was not accessible.”

**LEFT:** Georgia Tech researcher Hermann Fritz, left, interviews a survivor of the July 17, 2006 tsunami earthquake in Java to document survival strategies.

**A**nalyses of a classic, slow-rupturing tsunami earthquake whose massive waves devastated the coast of Java, Indonesia, in the summer of 2006 are providing insight to seismologists and engineers, who want to better understand these rare events, recommend strategies to improve safety and perhaps provide long-range forecasts of potential danger zones worldwide.

Among the surprises is data indicating that a secondary underwater movement amplified the original tsunami to create a wave run-up more than 60 feet high along more than a one-mile section of coastline. Data also raise the possibility that some regional geophysical characteristic may be making Java more vulnerable to tsunami earthquakes.

Researchers from across the globe presented analyses of seismic data, field survey information and modeling results of the July 17, 2006 tsunami earthquake at the American Geophysical Union's (AGU) December 2006 meeting.

Only about 0.1 percent of earthquakes of a 6.0 or larger magnitude on the Richter scale in the past 40 years

have been classified as tsunami earthquakes, but their potentially catastrophic impact demands investigation into why and where they occur, says session organizer Andrew Newman, an assistant professor of geophysics at the Georgia Institute of Technology's School of Earth and Atmospheric Sciences.

A tsunami earthquake is a slow-rupturing quake that occurs near the ocean floor. It uplifts a piece of the sea floor, and that deformation displaces water that propagates out to create a tsunami. Seismic data on the Java event revealed that the earthquake, which measured 7.7 on the Richter scale, did rupture slowly, Newman says. It created a deadly tsunami that hit a 300-mile stretch of Java's coastline and claimed more than 600 lives in a 125-mile-long, high-impact area.

The July 2006 tsunami earthquake was the second such event to occur on the Java trench in the past 40 years; the previous one happened in 1994.

“There may be something going on in this particular trench — some regional characteristic — that is increasing the potential for tsunami earthquakes in this area,” Newman notes. His

previous study of global data from 1970 to 2000 showed no indication of any seismic characteristics that made tsunami earthquakes occur more frequently in certain regions, but the Java event has renewed his interest in this possibility.

In another AGU presentation, Hermann Fritz, a Georgia Tech assistant professor of civil and environmental engineering, reported the findings of the International Tsunami Survey Team (ITST) that he led into Java about two weeks after the event.

Most areas were hit by waves not exceeding 30 feet, but the team documented waves greater than 60 feet high along a one-mile-long stretch of coastline on the island of Nusa Kambangan.

“This was an unusually high wave run-up for an earthquake with a magnitude of 7.7,” Fritz adds. “So we presume there was some local forcing, or underwater earth movement, such as a sub-marine landslide or slump, that may have been triggered by the earthquake and caused a larger tsunami to hit this local area.”

—Jane M. Sanders

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**BELOW:** The Java, Indonesia, tsunami earthquake in July 2006 measured 7.7 on the Richter scale. It created a deadly tsunami that hit a 300-mile stretch of Java's coastline and claimed more than 600 lives in a 125-mile-long, high-impact area. The tsunami earthquake was the second such event to occur on the Java trench in the past 40 years; the previous one happened in 1994.

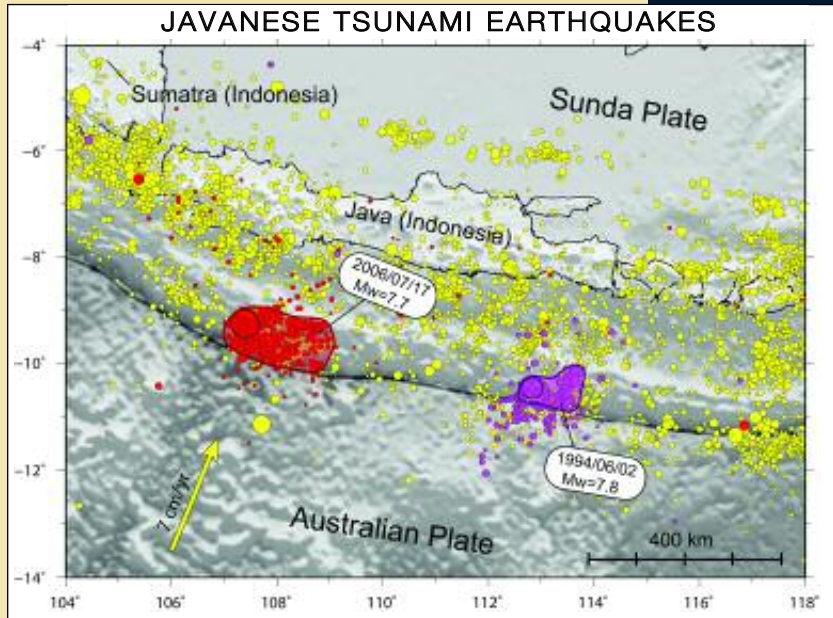


ILLUSTRATION COURTESY OF ANDREW NEWMAN

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## Water Needs

*Researchers outline plans to address drinking water and sanitation needs of developing countries.*

**W**orldwide, more than one billion people lack access to an improved water source, such as a rainwater collection or dug well, and two billion still need access to basic sanitation facilities, such as a latrine.

By 2015, the international community hopes to reduce by half the number of people without sustainable access to safe drinking water and basic sanitation.

This target for sustainable water and sanitation is just one of the United Nations Millennium Development Goals adopted in September 2000 at the Millennium Summit. These goals serve as the world's time-bound and quantified targets for addressing extreme poverty.

Local communities in the developing world and professional researchers are working to meet this goal. Researchers presented their work toward this end at the annual meeting of the American Association for the Advancement of Science (AAAS) in February 2007.

In the developed world, the moment a drop of water hits the ground, it goes into the water system until it becomes wastewater. Then it's treated and put it back into the system.

"We have a large-scale infrastructure in the United States to provide clean water," says Joseph Hughes,

chair of the Georgia Institute of Technology School of Civil and Environmental Engineering. "Using our current approach will not provide the rapid fix the United Nations is looking for in developing countries."

Hughes outlined four steps in solving the developing world's water and sanitation problems. First, researchers must determine how big the problem is, then analyze the dynamics of water distribution, understand the complexity of the systems required and, finally, create new approaches to water supply and sanitation through research and development. This includes new methods of storing, treating and disinfecting water and developing sanitation systems that minimize pathogen release.

Urbanization, climate changes, water scarcity and economic development will affect where water will be available in the future and where concentrated amounts of water will be required to meet the needs of large populations, Hughes says. The United Nations projects that by 2025, two-thirds of the world's population will live in areas that face water scarcity.

"Historically we've tried to go to groundwater sources, such as a well, to initiate improved water sources, but there's a very finite capacity in groundwater," Hughes notes. "We have to work

much harder to make ocean or surface waters safe."

International research has been under way to help improve the water supply and sanitation in developing countries. Georgia Tech Professor of Public Policy Susan Cozzens is leading new research, funded by the National Science Foundation, to determine whether these efforts have been effective. Cozzens plans to investigate how communities in developing countries share their knowledge. She will conduct case studies in urban and rural locations in four countries — Mozambique, South Africa, Costa Rica and Brazil — to answer these questions.

Her interest lies in how different places are addressing a lack of safe water and sanitation, and whether engineering, health and social science research plays any role in that.

"There's a research front out there, but we still need to think innovatively about prob-

lems with water supply and sanitation in developing countries," Cozzens says. "Even though there's only a little bit of social science (research) literature on water supply and sanitation, about half of it is about developing countries."

Cozzens' goal is to provide insight to international and local water authorities in developing countries on how to set the right conditions for people to learn and solve the problems of unsafe water and sanitation. This insight will come from studying the limitations of research knowledge in relation to this problem and studying communities in the developing world that have solved the problem, she adds.

— Abby Vogel

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Susan Cozzens

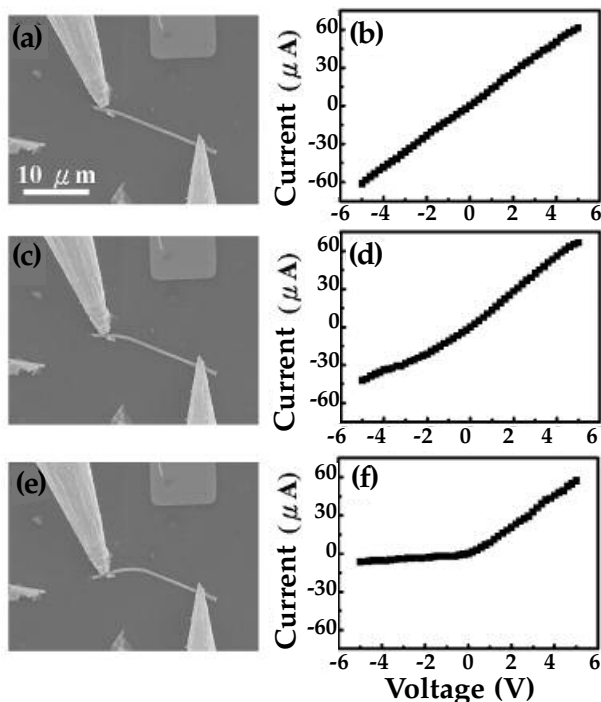


Joseph Hughes

PHOTO BY E. STAUB, COURTESY OF CDC AND THE CARTER CENTER



*ABOVE: This Nigerian woman is gathering drinking water from a local pond. But a Guinea worm larvae infestation necessitates that this water be filtered to remove the water fleas that carry the parasitic larvae of the Guinea worm.*



**ABOVE:** A piezoelectric diode is shown (a, c and e) in a sequence of scanning electron microscope images of bending a single zinc oxide nanowire between two probes. The graphs (b, d and f) show the corresponding current flow through the nanowire.

piezotronic sensors can detect forces in the nano- or even pico-Newton range.

Other piezotronic sensors can determine blood pressure within the body by measuring the current flowing through the nanostructures. And, an electrical connection made to one side of a bent zinc oxide nanostructure creates a piezotronic diode that limits current flow to one direction.

The nano-piezotronic mechanism takes advantage of the fundamental property of nanowires or nanobelts made from piezoelectric materials: bending the structures creates a charge separation — positive on one side and negative on the other. The connection between bending and charge creation also has been used to create nanogenerators that

produce measurable electrical currents when an array of zinc oxide nanowires is bent and then released.

Development of a piezotronic gated diode based on zinc oxide nanowires was reported Feb. 13, 2007 in the online advance issue of the journal *Advanced Materials*. Other nano-piezotronic components have been reported in the journals *Nano Letters* and *Science*. The research has been sponsored by the National Science Foundation, Defense Advanced Research Projects Agency, the National Institutes of Health and NASA.

— John Toon

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## Health & Safety Sleuths

It's no surprise that a construction site can be hazardous for workers, but how dangerous can a funeral home be?

Plenty, says Daniel Ortiz, manager of Georgia Tech's Safety & Health Consultation Program, which is housed within the Georgia Tech Research Institute's (GTRI) Electronic Systems Laboratory (ELSYS). Embalmers are exposed to a number of pathogenic microorganisms and chemicals, Ortiz explains. In fact, preliminary data from a GTRI occupational health study indicates that up to 20 percent of embalmers in Georgia funeral homes may be exposed to formaldehyde levels above regulatory limits. Some other unusual occupational hazards:

- Formaldehyde exposure can be a problem for workers who cut and sew wrinkle-resistant fabric.
- Jewelers who make and repair gold chains may be exposed to cadmium — a toxic metal.
- Nurses face a high risk of contracting blood-borne diseases from needles and other sharp instruments.

Although workplace safety has come a long way since the Industrial Revolution, reducing occupational hazards remains a challenge for U.S. employers, especially for smaller companies with fewer resources. In response, Georgia Tech's consultation program ([www.oshainfo.gatech.edu](http://www.oshainfo.gatech.edu)) provides technical expertise and training to help Georgia

companies create cleaner, safer environments for their workers.

In 2005, consultants visited more than 350 companies and identified 3,838 serious hazards, saving employers about \$3.8 million in potential penalties from the U.S. Occupational Safety and Health Administration (OSHA).

"Yet that's just the tip of the iceberg," Ortiz says. "It's hard to put a number on costs because any accident has far-reaching effects that go beyond workers' compensation and lost time."

For example, when an injured worker leaves a production line, it interrupts workflow, Ortiz explains. A replacement may need to be trained, causing further delays, and colleagues may need time to adjust to the new worker. Another performance factor is worker morale, which can be negatively affected by the accident.

Funded by OSHA, Georgia Tech's consultation program is free to companies with fewer than 250 workers. What's more, the program is confidential.

"Our only requirement is that companies must agree to correct all hazards and provide written verification of their actions within a reasonable time frame," says Art Wickman, a GTRI research scientist who supervises the consultation program's industrial hygienists. — T.J. Becker

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**ABOVE:** Nurses face a high risk of contracting blood-borne diseases from needles and other sharp instruments.



# SCIENCE

## Ovarian Cancer Protein Discovery

**A** new study suggests that ovarian cancer cells form by hijacking a developmental genetic process normally used to form fallopian tubes.

Scientists at the Georgia Institute of Technology and the Ovarian Cancer Institute discovered that the protein PAX8 is involved in the development of fallopian tubes and is present in ovarian cancer cells, but not in normal ovarian tissue. The discovery not only provides a new target for diagnostic and therapeutic interventions, but also opens new avenues for basic research in ovarian cancer pathology. The research appeared in Volume 104, Issue 3 of the journal *Gynecologic Oncology*.

"Our finding sustains the promise of a molecular genetic understanding of different cancers and emphasizes the importance of describing cancer in the context of normal human development that has gone awry due to genetic and epigenetic alterations," says Nathan Bowen, a Georgia Cancer Coalition Distinguished Cancer Scientist at Georgia Tech and the Ovarian Cancer Institute (OCI).

Using cancerous and non-cancerous tissue straight from the operating room, Bowen and fellow OCI researchers are investigating the molecular profile of ovarian cancer tissue to discover the causes of ovarian cancer, develop a reliable diagnostic blood test and understand the genetic basis of resistance to chemotherapy.

In 2003, a group from Stanford University researching breast cancer discovered that paired box gene 8 is expressed in ovarian cancer tissue, but not in breast cancer. Taking note of the Stanford group's results, OCI researchers began to investigate whether the gene and its products may be an important biomarker for detecting and researching the causes of ovarian cancer. They looked for evidence of PAX8, the protein made by paired box gene 8, which was the next step in establishing the gene as a biomarker.

Not only did they find PAX8 in the ovarian cancer cells, but also in the secretory cells that form fallopian tubes. In addition, they discovered that the protein is not expressed in the normal ovarian surface epithelium.

Bowen proposes that ovarian cancer begins by using PAX8 to direct an adult stem cell population found on the ovarian surface to proliferate and ultimately form ovarian cancer.

— David Terraso

© Contact: Nathan Bowen at 404-385-6628 or [nathan.bowen@biology.gatech.edu](mailto:nathan.bowen@biology.gatech.edu). Read more at: [www.gatech.edu/news-room/release.php?id=1293](http://www.gatech.edu/news-room/release.php?id=1293)

## Explosive Growth

**P**olywad Inc., a small middle-Georgia ammunition manufacturer, is poised for some rapid growth thanks to a recent Department of Defense contract — and broad-ranging assistance from Georgia Tech's Enterprise Innovation Institute.

Macon, Ga.-based Polywad, maker of patented Spred-R ammunition and other shotgun products, is gearing up to make specialized rounds for the U.S. military. Critical to the move are a pair of Small Business Innovation Research (SBIR) grants totaling \$1.9 million.

That funding is helping Polywad build and equip a new manufacturing plant in Roberta, Ga., near Macon. Company officials expect to transfer operations to the new site soon and to increase their workforce significantly.

"We're excited to be moving into a new purpose-built shop that's going to have all the safety and security features the Department of Defense requires," says Jay Menefee, Polywad's founder and president.

SBIR funding comes from federal agencies such as the Department of Defense; its purpose is to use small businesses to develop new technologies and products that the agencies need. In Polywad's case, the grants were facilitated by the Enterprise Innovation Institute, a business-assistance and economic development group based at the Georgia Institute of Technology. The Enterprise Innovation Institute has also supported Polywad by providing advisers in business planning, quality control and manufacturing technology.

"Polywad is among the Georgia companies that the Enterprise Innovation Institute has been able to assist on multiple levels," says John Mills, manager of the SBIR Assistance Program for the state of Georgia, a division of

PHOTO BY GARY MEEK



*ABOVE: Georgia Tech assistance is helping Macon, Ga.-based Polywad Inc. become a supplier of specialized rounds for the U.S. military.*

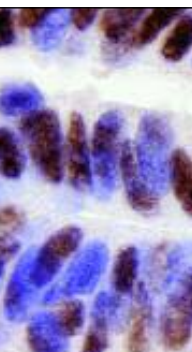
the Enterprise Innovation Institute that helps companies win SBIR grants. Mills and other Enterprise Innovation Institute staff members helped Polywad with SBIR applications and in developing the means to manufacture the company's innovative products.

Polywad manufactures many shot-shell products available to the public. But the company also makes a special round, the Polyshok, that's available only to law enforcement and similar agencies.

The Polyshok round devastates its target, but only in a limited area. The metal-powder slug's energy disperses so quickly that it's usually harmless even to persons in close proximity or immediately behind the target, Menefee says.

— Rick Robinson

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*ABOVE: Ovarian cancer tissue shows PAX8 — the protein made by paired box gene 8, which is expressed in this type of cancerous tissue — stained in black.*