Research Horizons

Spring/Summer 2001

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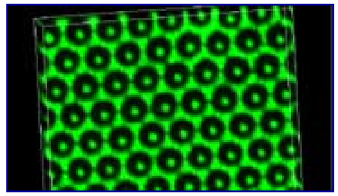

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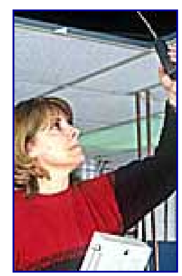

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Research Horizons
Volume 18, Number 3
Spring/Summer 2001
A publication of the
Georgia Institute of Technology

Editor
Jane M. Sanders
jane.sanders@edi.gatech.edu
404/894-2214

Graphic Design
Everett Hullum

Web Design
Rick Robinson

Administration
Dr. Edward Reedy
Director, GTRI, and Vice President, Georgia Tech
Dr. Charles Liotta
Vice Provost for Research and Dean of Graduate Studies, Georgia Tech
John Toon
Manager, Research News and Publications Office

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Research News and Publications Office
Georgia Institute of Technology
430 Tenth Street, N.W.
Suite N-116
Atlanta, Georgia 30318
(Telephone: 404/894-6986) (Fax: 404/894-4545)

ISSN #1060-6696

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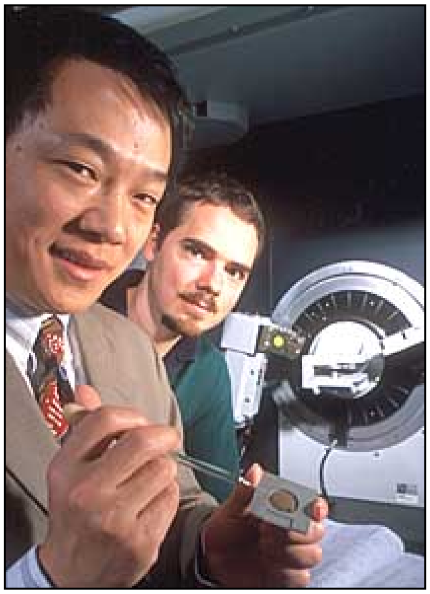
The Next BIG Thing... Is Very Small

By John Toon

IN THE 1997 MOTION PICTURE "Men in Black," extraterrestrial forces threaten to destroy Earth unless a stolen galaxy is quickly returned. The turning point of the story comes when the good guys realize that galaxies can be small enough to fit in a pocket.

photo by Gary Meek



(300-dpi JPEG version - 390k)

Appreciating nanoscience and nanotechnology requires a similar recalibration of size scales. Scientists and engineers in this burgeoning field work in a world visible only under powerful microscopes. But don't let size deceive – researchers see huge advances ahead in cancer detection and therapy, dramatic size and cost reductions for electronics, improvements in sensors, better catalysts to clean the environment, amazing new materials for defense applications, stronger metals – and a host of other benefits.

At the Georgia Institute of Technology, nearly 50 faculty members pursue research projects classed as nanoscience and nanotechnology, and their numbers are growing. The field is inherently interdisciplinary, drawing on expertise in physics, chemistry, electronics, materials science, computer science, biology, bioengineering, mechanical engineering and chemical engineering. To facilitate collaboration and share costly equipment, Georgia Tech formed the Center for Nanoscience and Nanotechnology last fall.

Just how small is nanoscale? A nanometer is one-billionth of a meter. Written as a fraction, that would be 1/1,000,000,000th of a meter. Five hydrogen atoms side by side span about one nanometer. The cells of our bodies stretch into the thousands of nanometers. At 100,000 nanometers, that old standby for size comparisons – the width of a human hair – seems positively gigantic. The head of a pin measures a million nanometers.

But smallness alone does not account for all the interest in the nanoscale. Because they share size scales with light waves and interact with electrons that can no longer behave like particles, nanoscale structures push the envelope of physics, moving into the strange world of quantum mechanics. That's both good and bad, offering challenges and opportunities.

Building a nanomachine or nanostructure therefore involves more than scaling everything down. At nanometer sizes, inertia critical to old-fashioned motors no longer has meaning. Friction changes, and gravity hardly matters. Nanoscale versions of materials differ significantly from those same materials at "bulk" sizes.

Beyond unique properties, the nanoworld offers the possibility of creating materials that have never existed before, building anew from the atom up. Using breakthrough tools like the scanning probe microscope, researchers can already move atoms around like checkers on a board.

"This is the next technology revolution," says Zhong L. Wang, director of Georgia Tech's Center for Nanoscience and Nanotechnology and a professor in the School of Materials Science and Engineering. "Nanotechnology will allow us to achieve revolutionary advances in many different areas. It's a very broad science, and will impact each and everyone's life."

Wang counts five advances that make the nanorevolution possible:

- Development of the scanning and transmission electron microscopes and scanning tunneling and atomic force microscopes, revolutionary technologies allowing researchers to see the nanoworld, even manipulate it.
- Nanoscale devices and engineering as the critical challenge to the future roadmap for microelectronics.
- Development of novel structures, such as fullerenes and carbon nanotubes, breakthrough structures that helped scientists realize the potential of the nanoworld.
- Appreciation for the effects of quantum mechanics, and structures such as quantum dots to take advantage of them.
- Powerful computers and software powering simulations to allow scientists to understand the phenomena at nanoscales.

Nanoscience and nanotechnology have received plenty of hype, so talk of advances mixes with words of caution.

Ashok Saxena, chair of Georgia Tech's School of Materials Science and Engineering, notes that every important advance must overcome unforeseen difficulties moving from the lab to real-world application. He compares today's nanoscience and nanotechnology to the burst of enthusiasm greeting advances in superconductivity during the mid-1980s.

"It was supposed to be revolutionary and change a lot of things," he notes. "We are only now beginning to see devices that use superconducting materials. Only time will tell how significant the contributions made by nanoscience and nanotechnology will be."

Others suggest the real implications may be beyond our current grasp.

"The most important results might not even be the things we are thinking about today," says Mostafa El-Sayed, Regents Professor of chemistry and director of the Laser Dynamics Laboratory. "I don't think it will be as great as some people predict, but there will certainly be interesting developments coming out of it."

Success in the nanoworld demands a different way of thinking – perhaps not unlike the good guys who had to accept the idea of a pocket-sized galaxy to save the Earth.

"We are still thinking with the mind of the huge world," El-Sayed says. "We may find that some of what we think are problems, in that small world are really very useful. We just don't know where it will lead. There is a lot of science yet to be done before the engineers can work with it."

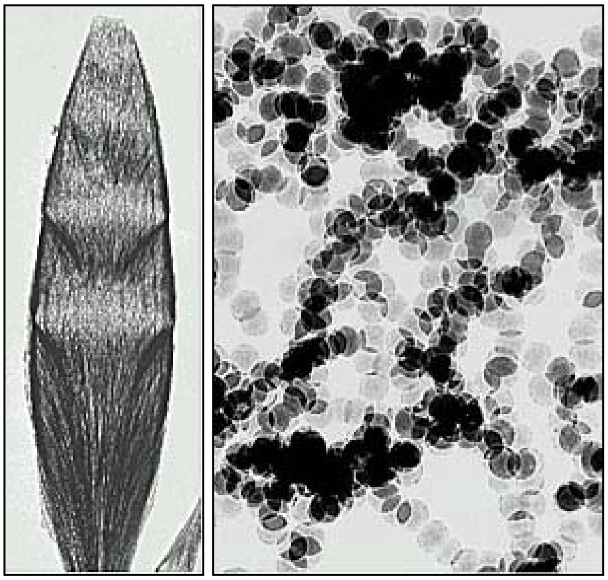
For more information, contact Zhong Wang, School of Materials, Science and Engineering, Georgia Tech, Atlanta, GA 30332-0245. (Telephone: 404-894-8008) (E-mail: zhong.wang@mse.gatech.edu)

The Next Big Thing:

Making Silicon Nanowire, Nanotubes and Nanospheres

Silicon and its oxide – silica – find widespread industrial applications and form the backbone of modern microelectronics. Work by Jim Gole, Mark White and collaborators is opening potential new silicon uses in nanocatalysis, nanosensors and nanoelectronics – while blazing a nanoscale trail for materials such as tin oxide and gallium nitride.

Using a simple and flexible high-temperature synthesis technique, the Georgia Tech researchers produce nanowires, nanotubes, nanospheres, "nanodiskettes" and nanofiber arrays from silicon, silica, silicon carbide and tin oxide. Operating at 1,300 to 1,500 degrees Celsius, the vapor-liquid-solid (VLS) process generates structures that are largely defect-free.



Georgia Tech researchers produce high-quality nanostructures from silicon and silica, including bundles of silica fiber (left) and silica nanospheres 30 nanometeres in diameter (right).

"We have developed a simple and generalized technique to make these nanostructures," explains Gole, a professor in the School of Physics. "We can make virtually any structure we want by putting the right materials together in the right spatial configuration under the right conditions."

Researchers vary the gas mixture, pressure, flow rate and starting materials to produce:

- Nanowires with 20-nanometer cores of crystalline silicon surrounded by 10-nanometer sheaths of silica.
- Silica nanospheres in uniform sizes from 8 to 45 nanometers. By coating the nanospheres with copper, White – a professor in the School of Chemical Engineering – produces catalytic structures that convert ethanol to aldehyde more efficiently than conventional catalysts. The nanospheres could replace silica powders now used for catalytic supports.
- Silica nanotubes that grow from silicon substrates. The nanotubes have outer diameters of 70 nanometers and walls 20 nanometers thick, leaving 30-nanometer channels that may have applications in high-molecular-weight hydrocarbon catalysis.
- Nanofiber arrays that resemble brushes.
- Biaxial fibers composed of silicon and silicon carbide with potential electronic uses.
- Tin oxide nanowires, nanotubes and disc-shaped structures dubbed "nanodiskettes." Beyond sensor applications, the nanotubes may be useful as chemical reactors.

The group has also succeeded in placing tin oxide nanocrystallites onto silica nanospheres.

The VLS synthesis process uses double concentric alumina tubes heated in a furnace. Precursor materials, such as a 50-50 mixture of silicon and silica, are placed in a crucible within the tubes, and pressurized argon gas is flowed through. Nanostructures form in a cooled region at one end of the tubes.

The researchers will soon lower their process temperature to accommodate production of gallium nitride structures.

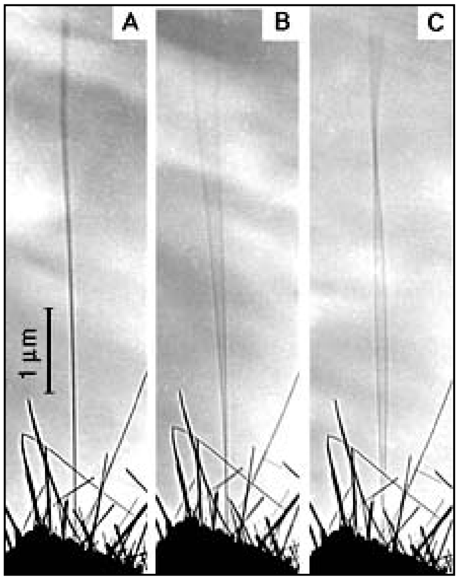
For more information, contact James Gole, School of Physics, Georgia Tech, Atlanta, GA 30332-0430. (Telephone: 404-894-4029) (E-mail: james.gole@physics.gatech.edu); or Zhong Wang, School of Materials, Science and Engineering, Georgia Tech, Atlanta, GA 30332-0245. (Telephone: 404-894-8008) (E-mail: zhong.wang@mse.gatech.edu)

The Next Big Thing:

Measuring the Tiniest of Structures

Nanoscience provides a promising collection of materials for a new generation of devices and structures. But before these new materials go to work, their properties must be thoroughly understood and documented.

Georgia Tech researchers Walter de Heer and Zhong L. Wang use a straightforward technique – mechanical resonance induced by an oscillating electrical voltage – to measure the bending strength of carbon nanotubes produced by two different processes.



Carbon nanotubes offer intriguing potential applications, but to use them scientists must gain a thorough understanding of their materials properties. Georgia Tech researchers use mechanical resonance induced by an oscillating electrical voltage to measure the bending strength of the tubes.

The work, which also correlates strength measurements to observable defects, will help engineers select the right type of nanotube for new applications as diverse as ultra-light composites and low-power field emission displays.

"We are able to make a quantitative comparison, with a real number to describe how the bending modulus differs," explains Wang, director of Georgia Tech's Center for Nanoscience and Nanotechnology, and a professor in the School of Materials Science and Engineering. "This work gives theoretical scientists data to model individual nanotubes."

Wang and de Heer – a professor in the School of Physics – compare nanotubes produced by high-temperature carbon arc discharge to structures grown in a catalyst-assisted pyrolysis process. In the latter, they found significant strength differences caused by point and volume defects.

Wang believes catalytically grown nanotubes offer advantages for lightweight composites, where defects could help interlock tubes to keep them from pulling out of the matrix. However, those same defects could cause problems in electronic applications, where nanotubes produced by carbon arcs may be superior.

Measurement begins by gluing a single nanotube to a tiny gold ball in a specially prepared transmission electron microscope sample holder. The tube is aligned near another gold ball, and an oscillating electrical voltage applied. Adjusting the frequency induces a measurable mechanical resonance in the tube.

By knowing the outer diameter, inner diameter and density of the nanotube, researchers can determine the bending modulus from the frequency at which it resonates. Observation in the transmission electron microscope correlates defects with strength.

Wang and de Heer also measured the conductance of a single carbon nanotube at room temperature. The current density that a single nanotube can carry is higher than any other material at room temperature, suggesting the possibility of using carbon nanotubes as interconnections in nanoelectronics. The work was reported in the journal *Science*.

For more information, contact Zhong Wang, School of Materials, Science and Engineering, Georgia Tech, Atlanta, GA 30332-0245. (Telephone: 404-894-8008) (E-mail: zhong.wang@mse.gatech.edu); or Walter de Heer, School of Physics, Georgia Tech, Atlanta, GA 30332-0430. (Telephone: 404-894-7879) (E-mail: deheer@electra.physics.gatech.edu)

Research Horizons

The Next Big Thing:

Amazing Metal Nanoclusters and Nanoparticles

More efficient catalysts. Improved sensors. A new optical data storage technique. Fluorescent labels for biological studies.

These are just a few of the applications being developed by Georgia Tech researchers to take advantage of the unique properties found in nanometer-scale metals.

photo by Gary Meek

Thin films of silver nanoclusters could provide a new means for storing data optically. Researchers Robert Dickson, Lynn Peyser and Amy Vinson expose a silver nanocluster sample to green laser light and study the resulting fluorescence. Typical responses are shown on the computer monitor behind them. (300-dpi JPEG version - 827k)

In the Laser Dynamics Laboratory at the School of Chemistry and Biochemistry, Mostafa El-Sayed and colleagues have studied catalytic properties of nanoparticles since the mid-1990s. The El-Sayed group reported in Science that because nanoparticles are so small, it was possible to synthesize them with different shapes. Now they are examining the different catalytic properties the various shapes might have for industrial and environmental uses.

Catalytic reactions take place only on the surface of these materials. Atoms not exposed to the reaction cannot participate, so increasing the percentage of atoms with surface exposure maximizes use of the costly platinum or palladium catalysts. Up to 70 percent of atoms in nanoscale catalysts can be involved in reactions, compared to a very small percentage of atoms in bulk catalysts.

"Most of the atoms then are helping you in the reaction, so if you are using a very expensive material, you don't need as much," El-Sayed explains. "The efficiency per gram of material can be orders of magnitude higher." Furthermore, nanoscale catalysts are more efficient than bulk catalysts and thus can catalyze reactions at lower temperatures to save energy.

But the nanoparticles tend to aggregate, forming larger and less efficient structures unless "capped" by a polymer material. That capping, however, reduces the surface available for catalysis. And researchers must devise a structure to hold the tiny particles without the capping material.

"We have to weigh these things against each other," El-Sayed notes. "It is always a compromise."

Laser Dynamics Laboratory researchers also study the unique optical properties of gold nanoparticles and nanorods. At the nanometer scale, these metal particles absorb light in unique ways, producing characteristically bright red colors that once found use in stained glass windows. The phenomena may find more modern use making sensors more efficient. The luminescent ability of gold nanorods may also find applications in imaging.

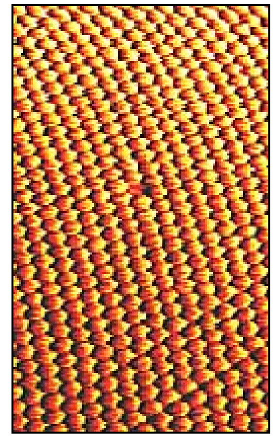
Robert Whetten also studies the unique optical properties of gold at the very smallest of scales. Examining nanoclusters containing between 20 and 40 gold atoms encapsulated by an ordinary biomolecule, he and Gregory Schaaff found distinctly chiral properties in the way the nanoclusters absorb light.

Theory had suggested such right-handed and left-handed absorption properties, but Whetten and Schaaff reported the first experimental evidence in a *Journal of Physical Chemistry* paper.

"When clusters are prepared this way, we see that the conduction electrons in the gold circulate in such a way as to have the unique optical effect of preferring one direction of circularly polarized light over the other direction," explains Whetten, a professor in the School of Physics and the School of Chemistry and Biochemistry.

The study measured nanoclusters created by attaching glutathione - a common sulfur-containing tripeptide - to individual gold atoms. In the resulting gold-glutathione polymer, gold atoms make no direct contact with one another. Decomposing the polymer produces the gold nanoclusters, which have glutathione molecules adsorbed to their surface so as to physically limit the number of metal atoms that could join each cluster.

The phenomena could be used for labeling biological molecules during experimentation.



At the nanoscale, metal particles behave differently than they do at bulk quantities. Gold nanoparticles and nanorods absorb light in unique ways, producing characteristic colors. (Larger JPEG version - 304k)

Silver nanoclusters composed of 2 to 8 atoms also produce interesting optical properties, demonstrating fluorescence that could lead to a new type of optical data storage. Writing in the journal Science, Georgia Tech researchers described binary optical storage based on writing and reading simple images recorded on thin films of silver oxide nanoparticles.

"These nanomaterials have a remarkable new property: When you shine blue light with a wavelength of less than 520 nanometers onto them, you switch on their ability to fluoresce," explains Robert M. Dickson, an assistant professor in the School of Chemistry and Biochemistry. "You can then read the fluorescence nondestructively by illuminating the clusters with longer-wavelength light."

The researchers begin by producing extremely thin films (less than 20 nanometers thick) of silver oxide nanoparticles on a glass slide. They then selectively expose portions of the film to light in the blue spectrum. The light chemically reduces particles near the surface of the film, partially converting them to clusters of silver atoms. When researchers expose these photo-activated silver clusters to longer wavelength green light, the clusters fluoresce strongly, emitting red light. Silver oxide particles not photo-activated by exposure to blue light don't fluoresce.

Studied under a microscope, the individual silver particles show an additional property that may be useful for increasing the density of optical data storage.

"If you look at an individual particle through the microscope, you see green emission, then red emission, then yellow emission all from the same particle," Dickson says. "Not only are you generating fluorescence, but you presumably are also changing the size and/or geometry of the cluster, which causes it to emit different wavelengths."

By using the right distribution of particle sizes, these multi-color emissions could allow storage of more than one bit of information in each data point. Distributed in a three-dimensional matrix, the particles could provide a dense storage medium that could be written and read in parallel.

Simple images stored on the silver oxide film can be read nondestructively by green light for at least two days, the longest time the researchers studied them. Though they have demonstrated an ability to optically write and read information, the researchers do not yet know if their film can be optically erased and rewritten.

For more information, contact Mostafa El-Sayed, School of Chemistry and Biochemistry, Georgia Tech, Atlanta, GA 30332-0400. (Telephone: 404-894-0292) (E-mail: mostafa.el-sayed@chemistry.gatech.edu); or Robert Whetten, School of Chemistry and Biochemistry, Georgia Tech, Atlanta, GA 30332-0400. (Telephone: 404-894-8255) (E-mail: robert.whetten@chemistry.gatech.edu); or Robert Dickson, School of Chemistry and Biochemistry, Georgia Tech, Atlanta, GA 30332-0400. (Telephone: 404-894-4007) (E-mail: robert.dickson@chemistry.gatech.edu)

The Next Big Thing:

Improving a Key Weapon Against Cancer

Chemotherapy is one of the most potent weapons in the battle against cancer. But because the powerful drugs circulate throughout the body, carried by the bloodstream, they often harm healthy cells while attacking the malignant ones.

Research on nanometer-scale particles with magnetic properties may allow better targeting of chemotherapy, potentially boosting its impact on cancer while reducing effects on healthy cells.

Rina Tannenbaum and John Zhang are pursuing different aspects of a promising new technique that would use magnetic nanoparticles to deliver chemotherapy drugs directly to cancer cells. After injection into the body, the particles would be guided to tumor sites by external magnetic fields. Once there, the particles – some as small as 2.5 nanometers – would bind to the cancer cells and deliver their drug payloads.

"This technique would put the specific drug you need directly into the cells you want to kill, affecting a minimal number of healthy cells," says Tannenbaum, an associate professor in the School of Materials Science and Engineering. "This could make the side effects of chemotherapy much less pronounced and allow you to zap the cancer cells with a higher drug concentration than you could otherwise provide. Both the localization and concentration could be very helpful in treating cancer."

photo by Gary Meek

Magnetic nanoparticles attached to chemotherapy drugs could increase therapeutic dosages while reducing side effects. Researchers John Zhang and Adam Rondinone prepare a sample of magnetic nanoparticles for analysis by X-ray diffraction. (300-dpi JPEG version - 644k)

With Georgia Tech colleagues, she works with metallic nanoparticles "capped" by polymeric materials such as polystyrene. The polymer prevents the nanoparticles from aggregating into larger particles and provides locations – reactive sites – at which molecules of the chemotherapy drug can be tethered like skiers behind a powerboat.

Tannenbaum's research so far has yielded good control over particle size, which appears related to polymer concentrations in the one-step chemical reaction forming the nanoparticles.

Though promising, her technique faces important hurdles. The polymer capping must withstand harsh conditions in the body. And chemical bonds between the drug and polymer must be strong enough to hold together in the bloodstream, yet weak enough to release when the particle binds to cancer cells.

Zhang, an assistant professor in the School of Chemistry and Biochemistry, has learned to precisely control the size and magnetic properties of his nanoparticles through variations in chemistry and process conditions. His goal is a "recipe book" that researchers could use to produce magnetic nanoparticles with the specific properties needed for a variety of applications, such as drug delivery, enhancement agents for diagnostic tests and replacement of radioactive tracers.

"We are understanding the fundamental ways to control the properties of these particles, chemically manipulating the magnetic interactions at the atomic level," he explains. "We want to make the connection between these atomic-level interactions and the macroscopic behavior we want in these materials."

Zhang and his colleagues have also taken another critical step, demonstrating that antibodies attached to the surface of their nanoparticles maintain their bioactivity. In use, specific antibodies on the nanoparticles would recognize and bind to receptors on the cancer cells, like a key in a lock. Once bound to the target cells, the particles would release their load of chemotherapy drugs.

Using surface chemistry techniques, Zhang has also camouflaged the surface of his particles to help them get past the body's immune system.

For more information, contact Rina Tannenbaum, School of Materials Science and Engineering, Georgia Tech, Atlanta, GA 30332-0245. (Telephone: 404-385-1235) (E-mail: rina.tannenbaum@mse.gatech.edu); or John Zhang, School of Chemistry and Biochemistry, Georgia Tech, Atlanta, GA 30332-0400. (Telephone: 404-894-6368) (E-mail: john.zhang@chemistry.gatech.edu)

![Research Horizons]

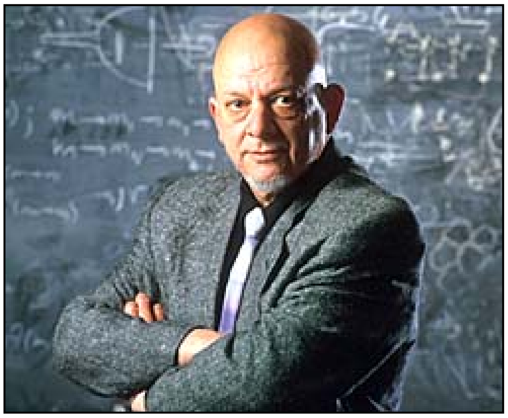
The Next Big Thing:

Charting the Nanoelectronic Future

Uzi Landman and Kevin Brennan study devices and structures that are at the limits of today's technology. Using powerful computer simulations based on established physical principles, they explore the world of the very small to provide guidance for tomorrow's device designers – suggesting appropriate materials, warning of pitfalls and recommending routes to avoid.

Director of the Center for Computational Materials Science and a professor of physics, Landman relies on supercomputers to understand how thousands of atoms and molecules interact under the influence of quantum mechanics. He and his research team examine how wires just a few atoms in diameter will behave, what might be necessary to operate nanoscale jets and how unique molecular effects may hamper lubrication in tiny machines.

photo by Gary Meek



Simulations based on established physical principles help researchers understand the unusual behavior of materials at the nanoscale. Uzi Landman pioneered the use of supercomputer-based molecular dynamics simulations to study the unique properties of nanowires, nanojets and other structures.

"Atomistic simulation methods allow interrogations of complex materials systems with a resolution in space and time that is often not possible by other theoretical approaches," he explains. "In such 'numerical experiments,' researchers can investigate the behavior of matter under conditions that are sometimes difficult, hazardous or impossible to realize in the laboratory."

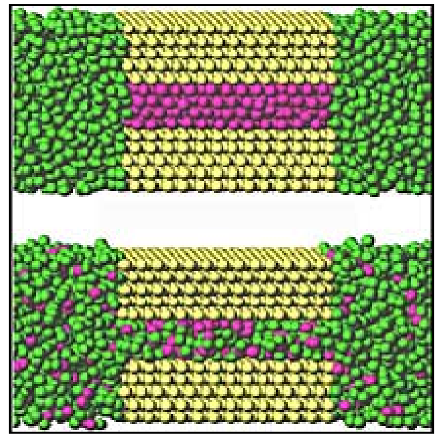
The simulations often show dramatic differences between materials at the nanoscale and those same materials at more familiar-size scales. Landman adds, "Small really is different."

Among the predictions from his molecular dynamics simulations:

- Liquid jets just a few nanometers in diameter should be technically possible, though their propagation will differ from larger jets and require special operating conditions.
- Highly confined fluids composed of molecular mixtures segregate themselves by size, with longer-chain molecules adsorbing near the surfaces and smaller ones remaining in the center of the confining gap.
- Building nanowires from clusters of silicon atoms, rather than atom-by-atom, could solve the statistical problems involved in doping silicon to improve its properties at the small scale.

With more than a decade of experience simulating small structures, Landman has now seen many of his predictions borne out as experiment catches up with theory. In November, he won the Feynman Prize in Nanotechnology (Experimental) for pioneering work in computational materials science.

Brennan, a professor in the School of Electrical and Computer Engineering, studies the unique properties of next-generation compound semiconductors. His work on electron transport, failure modes and other effects will help nanoelectronic device designers of the future choose the right materials.



Molecular dynamics simulations show unusual behavior of lubricant molecules in confined spaces.

While Brennan focuses primarily on wide band-gap materials for high-powered, high-frequency telecommunications devices, his predictions also apply to traditional silicon.

"We start from the fundamental physical principles of the electronic structure and calculate what happens as electrons move through the crystal and interact with the lattice," he explains. "We can put all of the factors into our simulator and predict with reasonable certainty what the electrons are really experiencing. From there, we can move to device geometry and explain how the device is going to behave. This is particularly important in nanostructures as we miniaturize devices."

Designers must be able to anticipate device behavior under different conditions as they produce smaller microcircuits operating with higher electric field strengths. To handle those fields without breaking down or producing unpredictable behavior, new materials such as gallium nitride and silicon carbide will be needed. The information Brennan's group develops will help designers understand the trade-offs between device properties in these new materials – and suggest the most promising experimental routes for learning about them.

"We are the point people, out in front of the device designers, trying to understand what will be going on," he says. "We're helping choose the optimal routes to follow in selecting materials and building devices to minimize the cost and improve performance."

For more information, contact Uzi Landman, School of Physics, Georgia Tech, Atlanta, GA 30332-0430. (Telephone: 404-894-3368) (E-mail: uzi.landman@physics.gatech.edu); or Kevin Brennan, School of Electrical and Computer Engineering, Georgia Tech, Atlanta, GA 30332-0269. (Telephone: 404-894-6767) (E-mail: kevin.brennan@ece.gatech.edu)

THE NEXT BIG THING

Making Silicon Nanowires....
Measuring Tiniest of Structures
Amazing Metal Nanoclusters
Improving Key Cancer Weapon
The Nanoelectronic Future
Teaching Old Process New Tricks
Military Meta Materials
Shining a Light on Cancer
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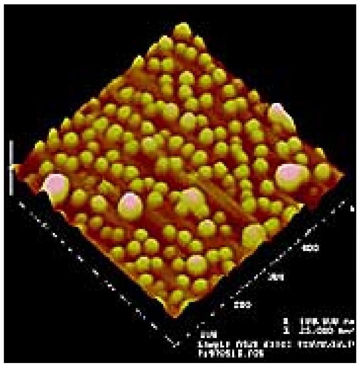
Nanoscale Optical Structures
Microelectronics Fabrication
Nanobelts Join World of Ultra-small

The Next Big Thing:

Teaching an Old Process New Tricks

In the microelectronics industry, molecular beam epitaxy (MBE) is used to grow thin films of materials with atomic-scale precision. April Brown and graduate student Jeng-Jung Shen are pushing the limits of MBE, hoping to gain more control of the process – enough to produce self-assembled quantum dots in the right sizes and locations for a new generation of electronics.



Self-assembled quantum dots.
(Larger JPEG version - 54k)

Quantum dots are bundles of atoms, typically 100 atoms in diameter and 10 atoms high. Because their electrons are confined to such a small area, the tiny structures possess unique properties that may be useful in the next generation of electronic devices.

But before MBE can be used to grow quantum dots useful to nanoelectronics, researchers must learn to control MBE well enough to consistently produce structures with uniform sizes in desired locations. Current technology produces randomly spaced quantum dots that often grow too large.

photo by Gary Meek

Molecular beam epitaxy (MBE) has long been important to microelectronics research. April Brown is pushing the limits of MBE to produce self-assembled quantum dots that could have novel applications to future generations of electronic devices. (300-dpi JPEG version - 857k)

"We'd like to be able to absolutely control where they are deposited, where they nucleate and what their size is," explains Brown, a professor in the School of Electrical and Computer Engineering. "The perfect material would be a three-dimensional volume in which you have an array of uniformly sized, regularly spaced quantum dots."

Brown's research team already grows three-dimensional arrays in which successive layers of quantum dots grow atop one another, separated by thin semiconductor films. The dots grow because of a cleverly mismatched crystalline structure; self assembly occurs because mechanical stresses in the successive layers encourage quantum dot growth at distortions in the crystalline structure. It's an impressive feat, but the researchers still cannot control where the first layer of dots forms.

"It's going to be difficult to achieve," Brown admits. "It's going to have to be achieved with surface patterning or some other technique yet to be developed."

The issue has relevance to more than quantum dots. If researchers can reach this goal, what they will learn will help them improve more conventional MBE applications – including Brown's long-term work with heterojunction devices formed at interfaces between dissimilar materials.

The work is supported by the Office of Naval Research, the Defense Advanced Research Projects Agency and the Air Force Research Laboratory.

For more information, contact April Brown, School of Electrical and Computer Engineering, Georgia Tech, Atlanta, GA 30332-0269. (Telephone: 404-894-5161) (E-mail: april.brown@ece.gatech.edu)

Research Horizons

The Next Big Thing:

Uncle Sam Wants... Military Meta Materials

Nanoscience and nanotechnology promise revolutionary change in medicine, electronics and a host of other areas. But what impact will they have on the nation's defense?

A research team from Georgia Tech, NASA and SRI International expects to provide an answer.

The researchers see tantalizing possibilities in the nanoworld, options available only by engineering new materials from the atom on up. Sponsored by the Defense Advanced Research Projects Agency (DARPA), their work focuses on "meta materials" for breakthrough antennas and new resistive magnetic, conductive and infrared coatings.

"We have largely reached the limit of what we can do in electromagnetics with the materials nature has provided," says Rick Moore, principal research scientist in the Signature Technology Lab of the Georgia Tech Research Institute (GTRI). "We now need to understand how to change the basic parameters of the materials we use. Nanoscience offers one potential technique to change those fundamental properties."

Moore and research engineer Douglas Denison head a team that includes scientists from two Georgia Tech academic colleges: Uzi Landman from the School of Physics and Mohan Srinivasarao from the School of Textile and Fiber Engineering. Landman offers a decade of experience in molecular dynamics simulation of nanoscale materials. Srinivasarao brings expertise in a novel self-assembly process for nanoscale structures.

The team brings together expertise from the nanometer-size scale – where quantum mechanics plays its tricks – on up to sizes that can be seen and touched. Denison explains, "We are taking the next step to bridge all of these size domains, from the quantum and micron scales all the way to a perceptible scale."

Building on GTRI's experience with electromagnetic materials, the four-year program begins with advanced modeling and basic science. It will conclude with production of nanomaterials possessing unique properties.

One possibility is a new material for the ground planes of future conformal antennas, the flat antennas on the sides of military vehicles. The ground plane increases antenna gain by redirecting electromagnetic energy outward. Physical laws dictate that it be separated from the antennas' radiating elements by a distance set by the wavelength of the energy. This limits the frequencies at which a single antenna performs well.

Researchers dream of a conductive magnetic material that would void these laws, making possible thinner antennas that work well over broad bandwidths. Nanoscience may make their dream a reality.

"Nanoscience offers an opportunity to make materials in the same way you would construct a building," Denison says. "You have a plan, and you work with beams and bricks to get the big structure you want. We won't be limited anymore to the bulk materials that nature has provided us."

For more information, contact Douglas Denison, Signature Technology Laboratory, Georgia Tech Research Institute, Atlanta, GA 30332-0800. (Telephone: 404-385-1261) (E-mail: doug.denison@gtri.gatech.edu)

The Next Big Thing:

Shining a Little Light on Cancer

Pancreatic cancer is a silent killer, often reaching an advanced stage before being diagnosed. Gang Bao and his colleagues hope to provide early detection of this killer using molecular-scale beacons that would find genetic signs of cancer and signal clinicians with a burst of fluorescence.

The molecular beacons consist of three parts: a fluorescent dye molecule and a "quencher" molecule on opposite ends of an oligonucleotide engineered to match specific genetic mutations associated with cancer. Initially, the two molecules are held close together in a hairpin shape, the quencher preventing fluorescence emission from the dye.

photo by Gary Meek

Molecular-scale beacons could offer an important new diagnostic tool for detecting pancreatic and other types of cancer. Researchers Gang Bao, Andrew Tsourkas and Carrie Williams examine fluorescence from a sample of the beacons using a confocal microscope in the Wallace H. Coulter School of Biomedical Engineering. (300-dpi JPEG version - 915k)

Delivered into cells, the beacons seek out and bind to the mutated genetic material, known as mRNA. This breaks the bonds holding dye and quencher together, producing a fluorescent signal visible microscopically.

The current design of beacons, however, is prone to digestion by cellular enzymes, which activates the beacons to create false signals. To overcome this difficulty, the Bao lab has developed a new dual-beacon system that detects the fluorescence resonance energy transfer (FRET) between two beacons bound to the same mRNA target, significantly increasing the detection sensitivity.

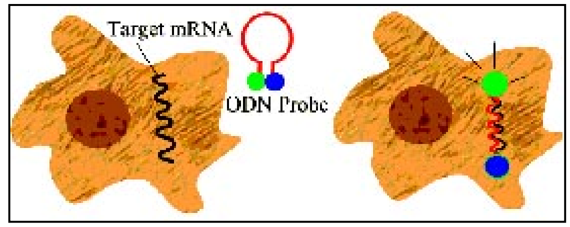
"This could become a very powerful clinical tool for cancer diagnosis," says Bao, an associate professor in the Wallace H. Coulter School of Biomedical Engineering. "If there are mutations in the cell, the beacons should find them. Cancer diagnosis based on molecular beacons should be much faster than any technique now available."

Bao, his Ph.D. student Andrew Tsourkas and collaborators at Emory University have so far shown that the technique can efficiently detect several common genes. They have also shown how the detection time and specificity depend on the structure of the beacons.

But their work faces many challenges. They must demonstrate that their FRET-enhanced molecular beacons will find the mutated mRNA quickly – within 30 minutes. They must also find better dye molecules to provide a detectable signal even if the mutation exists in just one of 10,000 cells under study.

The technique would be valuable in diagnostic testing. But to be really useful against pancreatic and other cancers for which no good screening tests exist, it would have to detect cancer markers in blood or other easily collected body fluid. Ultimately, Bao hopes the beacons – just a few nanometers in size – will be able to detect cancerous cells in the human body.

"Studies show that even if the difference between the mRNA for the cancer and the normal mRNA is only one base pair, the molecular beacons can still differentiate between the two," he says. "If we can detect the cancer early enough, very likely the outcome of cancer patients can be improved."



Molecular beacons bind to mutated genetic material and signal its presence with fluorescence.

In more basic research, Bao and his students use optical tweezers – piconewton forces generated by beams of photons from a high-powered laser – to quantify interaction of biomolecules such as proteins and DNA. For example, by anchoring one protein on a surface, they use the tweezers to measure the unbinding force required to separate it from another protein.

"This is an engineering study similar to the way we study the strength of steel," he explains. "We just have a nano-scale system and a much more delicate tool."

For more information, contact Gang Bao, Wallace H. Coulter School of Biomedical Engineering, Georgia Tech, Atlanta, GA 30332-0535. (Telephone: 404-385-0373) (E-mail: gang.bao@bme.gatech.edu)

THE NEXT BIG THING

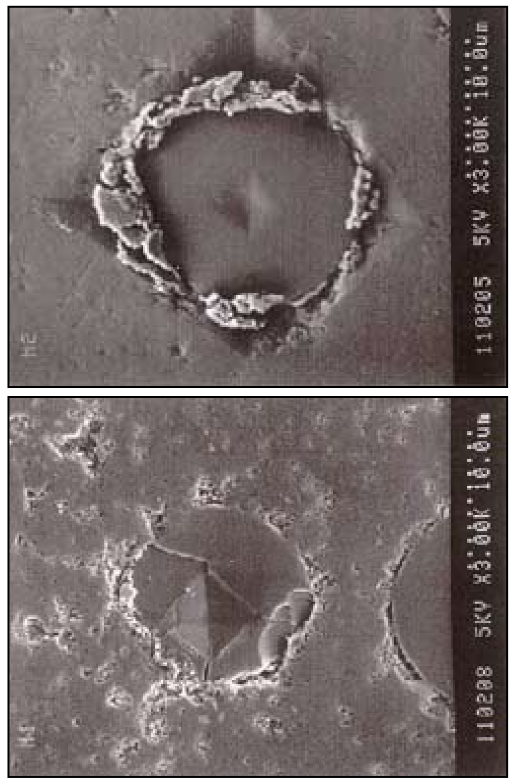
Making Silicon Nanowires....	Military Meta Materials
Measuring Tiniest of Structures	Shining a Light on Cancer
Amazing Metal Nanoclusters	Studying Nanostructured Materials
Improving Key Cancer Weapon	Nanoscale Optical Structures
The Nanoelectronic Future	Microelectronics Fabrication
Teaching Old Process New Tricks	Nanobelts Join World of Ultra-small

The Next Big Thing:

Studying Properties of Nanostructured Materials

Materials scientists have worked with metals like copper and nickel for many years, so the properties of these materials are well documented. But the availability of nanostructured versions of these familiar metals opens up possibilities for new and unique combinations of mechanical properties – and a whole new research frontier.

Nanostructured materials result from novel processing techniques that dramatically reduce the size of crystals that make up the bulk metals, dropping them from the micrometer- to nanometer-size scale. That alters the behavior of line defects in the crystalline structure known as dislocations, making the nanostructured metals orders of magnitude stronger than their traditional forms.



Studying nanostructures requires a new set of test equipment. Researchers using a diamond indentation tester to study the fracture toughness of nanofibers produced these images showing damage to silicon carbide fibers. (Larger JPEG version, top - 125k) (Larger JPEG version, bottom - 122k)

But even in the nanoworld, there is no free lunch. The strength increase may come at the cost of other important properties, a trade-off that provides an important new area for research.

"If you look at the performance of a metal in an aircraft, strength is only one of the properties that we care about," says Ashok Saxena, chair of Georgia Tech's School of Materials Science and Engineering. "It's also important to get the right amount of toughness, creep resistance, corrosion resistance and fatigue resistance. We don't know yet if these new materials will be optimal in all those properties."

The new nanostructured materials are also expensive, too costly to study using traditional test procedures. So researchers are developing new nanoscale testing techniques to investigate key properties using only small samples.

For example, Georgia Tech researchers use a diamond nanoindentation tester to study deformation and hardness properties of the new materials. The device presses a diamond tip just 10 nanometers wide into the sample under study. The force required to make the indentation and the total displacement of the tip together provide data useful to understanding the properties.

Atomic force microscopy also provides information about the new nanostructured materials. By furnishing a topographical view of the materials' surface, researchers can "see" features 3 to 5 nanometers high that provide evidence of metal fatigue. They also plan to modify the stage of a scanning electron microscope to obtain visual confirmation of the information obtained during deformation testing.

Saxena adds, "There is good reason to be optimistic about these new materials, but there is good reason to be cautious."

For more information, contact Ashok Saxena, School of Materials Science and Engineering, Georgia Tech, Atlanta, GA 30332-0245. (Telephone: 404-894-2888) (E-mail: ashok.saxena@mse.gatech.edu)

Research Horizons

THE NEXT BIG THING
Making Silicon Nanowires....
Measuring Tiniest of Structures
Amazing Metal Nanoclusters
Improving Key Cancer Weapon
The Nanoelectronic Future
Teaching Old Process New Tricks
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Shining a Light on Cancer
Studying Nanostructured Materials
Nanoscale Optical Structures
Microelectronics Fabrication
Nanobelts Join World of Ultra-small

The Next Big Thing:

Nanoscale Optical Structures Light the Way

The wavelength of light is measured in nanometers, so it's not surprising that optical scientists have a strong interest in a new generation of nanoscale devices for directing, amplifying, switching, processing, sensing and otherwise manipulating light.

In April, Georgia Tech researchers announced a new self-assembly technique for producing complex three-dimensional polymer structures with potential applications as photonic bandgap materials, optical waveguides, laser arrays and beam steering systems. Reported in the journal Science, the simple technique involves directing moist air across a polymer material dissolved in a fast-evaporating solvent. In its simplest form, the process requires only that researchers exhale across the polymer solution.

photo by Gary Meek

Nanoscale structures offer new applications for photonic band gap structures, optical waveguides, mirrors and other devices. Research scientist Jung Park uses a confocal microscope to study a self-assembled polymer structure that has potential photonic applications. (300-dpi JPEG version - 1.24Mb)

"This represents an easy way of making materials with the regular structure needed for optical and photonic applications," says Mohan Srinivasarao, a polymer chemist in the School of Textile and Fiber Engineering and School of Chemistry and Biochemistry. "This is completely a self-assembly process. We have shown that with very little work you can form nicely ordered structures."

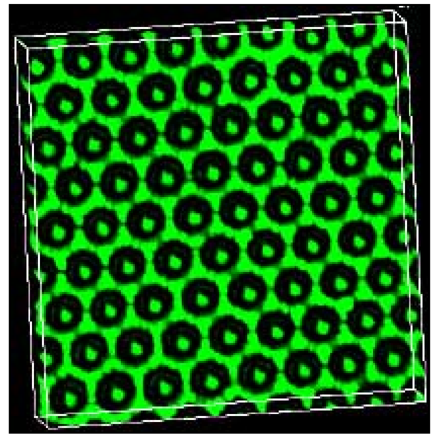
Supported by the National Science Foundation, Srinivasarao and colleagues produce interconnected arrays of spherical air bubbles in uniform sizes from 0.2 microns (200 nanometers) up to 20 microns in diameter.

The process begins with dissolving a polymer such as polystyrene in a fast-evaporating solvent such as toluene or benzene. The solution containing the dilute polymer is placed on a glass slide, and moist air is directed across it as the solvent evaporates rapidly, dropping the solution's temperature by as much as 25 degrees Celsius. Moisture from the warm air condenses on the surface of the solution, forming a layer of uniform-size droplets packed tightly together like billiard balls. Because the water is denser than the solvent, the layer of droplets sinks into the polymer, allowing another layer to quickly form on top of it.

The process repeats itself for one to two minutes until all of the solvent is evaporated. The water then evaporates layer by layer, leaving a highly ordered and interconnected network of air bubbles.

"We have focused on how to modify the refractive index so we can use these as a photonic bandgap material, which is the first application we will go after," Srinivasarao adds. "But what we will be able to do is limited only by the imagination."

In the nearby School of Materials Science and Engineering, Chris Summers leads a group investigating emissive and active photonic crystal structures for the near-infrared to visible spectral region. The group is investigating the properties of photonic crystals fabricated into thin films, as well as those formed by self-assembled opal and inverse opals, to tune and increase the intensity of luminescence in phosphors. They are also developing high-dispersion materials, and comparing the properties of two-dimensional thin-film photonic crystals with three-dimensional opal structures.



The hole diameter in this polymer-structure sample is 3.5 microns. (300-dpi JPEG version - 266k)

Developed over the past decade, photonic crystals are created by the self assembly of nanoparticles and the nanopatterning of optical materials to create a periodic dielectric constant that creates an optical band gap in the material. The crystals can act as optical cavities, waveguides or mirrors, offering researchers new mechanisms for controlling light.

"Photonic crystals offer new ways of adding to the functionality of optical materials and are expected to have a revolutionary impact on optical signal processing and data transmission systems for communications and displays," explains Summers, who is director of the Phosphor Technology Center of Excellence at Georgia Tech.

Fabricated from luminescent and elctro-optic materials, the crystals offer better control over the emission, spectral purity and dispersion properties of light. Ultimately, this will allow development of a range of new devices, such as displays with more highly saturated colors, faster response times and lower thresholds, and fast all-optical switches for optical communication and computing systems.

For more information, contact Mohan Srinivasarao, School of Textile and Fiber Engineering, Georgia Tech, Atlanta, GA 30332-0295. (Telephone: 404-894-9348) (E-mail: mohan.srinivasarao@textiles.gatech.edu); or Chris Summers, School of Materials Science and Engineering, Georgia Tech, Atlanta, GA 30332-0245. (Telephone: 404-385-0697) (E-mail: chris.summers@mse.gatech.edu)

The Next Big Thing:

Extending the Life of Microelectronics Fabrication

Semiconductors are perhaps the most complex products ever manufactured in volume, each memory or processor chip requiring more than 400 precision steps.

Thanks to increasing miniaturization, each new chip generation packs more capability than the last. Decades ago, Intel founder Gordon Moore set forth the expectation that chip capacity would double every 18 months. Since then, continued gains have fueled dramatic growth in the information technology industry.

But Moore's Law now faces significant technical challenges – one of the most important arising from the wavelength of light.

Creating circuits on semiconductor wafers requires a painstaking lithography process. Patterns are produced in a photoresist material using light projected through a mask. Portions of the resist struck by the light become more soluble than the other regions and can be washed away. An etching step then forms the intricate circuitry patterns by removing underlying material not protected by the resist.

Making smaller and smaller devices means using shorter and shorter wavelengths of light. But with feature sizes approaching the nanometer-scale, these shorter wavelengths no longer penetrate through the entire resist layer, setting the stage for failure in the etching step. Ultimately, a whole new process will have to be devised.

"We're not going to be able to do lithography the way we've done it for the past 30 years," notes Dennis Hess, a professor in the School of Chemical Engineering. "It's got to change in the very near future."

Hess and colleagues Cliff Henderson and Laren Tolbert hope to bypass the problems caused by short wavelengths. Their innovation, dubbed surface-initated polymerization, grows resist only where needed atop an extremely thin polymer layer that is activated by light. Alternatively, they can deactivate areas where resist should not be grown.

Because only a thin layer is needed to initiate growth of the resist, shorter wavelengths can be used – even into extreme ultraviolet and X-ray regions. So far, they've demonstrated an ability to create patterns and developed a practical resist material. But they still must show that the process can produce the kind of smooth walls, sharp edges and controllable patterns needed by circuit designers.

"We want to show that this is a viable technique for patterning small dimensions," Hess explains. "If it is, there will be a number of people very interested in trying this on actual device wafers."

He estimates that surface-initated polymerization could be implemented within three to five years.

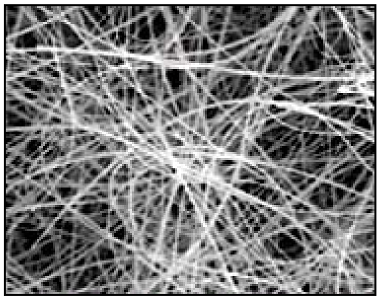
For more information, contact Dennis Hess, School of Chemical Engineering, Georgia Tech, Atlanta, GA 30332-0100. (Telephone: 404-894-5922) (E-mail: dennis.hess@che.gatech.edu)

Research Horizons

The Next Big Thing:

Nanobelts Join the World of the Ultra-Small

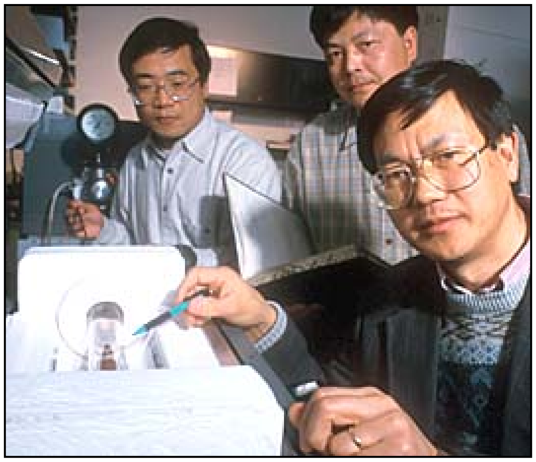
First came nanotubes, then nanowires, nanoclusters and nanoparticles. Now please welcome nanobelts to the growing, but still very small, world of nanometer-scale structures.



Microscope image shows a clump of ribbon-like nanobelts. (Larger JPEG version - 121k)

In March, Georgia Tech researchers reported in the journal Science that they had created a new class of structures just 10 to15 nanometers thick and 30 to 300 nanometers wide. Dubbed "nanobelts," the new structures could be the basis for inexpensive ultra-small sensors, components for improved flat-panel displays and "smart" windows for controlling the amount of heat and light entering buildings.

photo by Gary Meek



A new class of structures known as "nanobelts" (inset) may have applications in sensors, flat-panel displays and "smart" windows. A team of researchers including Zhong Wang, Zhengwei Pan and Zurong Dai produce oxide-based nanobelts in a high-temperature furnace. (300-dpi JPEG version - 843k)

Produced from semiconducting metal oxides, nanobelts offer important advantages over other nanoscale structures in electronic applications. Chemically pure, structurally uniform and largely defect-free with surfaces that don't require protection against oxidation, each nanobelt is made up of a single crystal.

"This is a vitally important area of nanotechnology," says Zhong L. Wang, director of Georgia Tech's Center for Nanoscience and Nanotechnology and a professor in the School of Materials Science and Engineering. "If we are successful at these applications, it may lead to major technological advances in nano-size sensors and functional devices with low power consumption and high sensitivity."

Wang and colleagues have so far produced nanobelts from oxides of zinc, tin, indium, cadmium and gallium. They believe other semiconducting oxides may also be used to make the structures.

"The crystallographic structure varies a great deal from one oxide to another, but they all have a common characteristic as part of a family of materials that have ribbon-like structures with a narrow rectangular cross-section," Wang explains. "In comparison to the cylindrical symmetric nanowires and nanotubes reported in the literature, these are really a distinctive group of materials."

Researchers begin production of the nanobelts by placing commercially available metal oxide powders in the center of an alumina tube. As argon or nitrogen gas flows through it, the tube is heated in a furnace to temperatures just below the melting point of the powders, approximately 1,100 to 1,400 degrees Celsius. The powders evaporate, then form the crystalline nanobelts as they return to solid phase on an alumina plate in a cooler part of the furnace. No purification is needed.

Finished nanobelts resemble clumps of cotton. Despite their origin in normally brittle oxides, the structures are flexible and can be bent 180 degrees without breaking.

For more information, contact Zhong Wang, School of Materials Science and Engineering, Georgia Tech, Atlanta, GA 30332-0245. (Telephone: 404-894-8008) (E-mail: zhong.wang@mse.gatech.edu)

Research Horizons

Preempting a "Creeping Disaster"

Drought prompting Georgia to develop a proactive management plan.

By Jane M. Sanders

PERIODS OF DROUGHT have naturally come and gone throughout history. In recent years, however, some regions of the United States have become more vulnerable to the effects of drought as pressures increase on natural resources.

Rain deficits are rising. Crops are dying on the vine, and lake levels are plummeting. Meanwhile, concern is growing among water managers and others. Already, 31 states have implemented drought management plans, five of which attack the situation proactively, rather than emphasizing emergency response. Georgia will soon be among the proactive because of planning by state officials and a team of scientists led by a Georgia Institute of Technology professor.

photo by Alan Hope

The boat ramp at Clark's Bridge Park on Lake Lanier was closed because of the lake's low water level. A continuing drought in Georgia caused the U.S. Army Corps of Engineers, which manages Lanier, to close virtually all such facilities late last year. But recent rains have led to the reopening of nearly half of the lake's 57 ramps.

"Drought is a 'creeping disaster,'" says Anne Steinemann, an associate professor in the City and Regional Planning Program of the Georgia Tech College of Architecture. "It's easy to photo by Gary Meek

Anne Steinemann, an associate professor in the City and Regional Planning Program of the Georgia Tech College of Architecture, is leading a team of experts who are assisting Georgia government officials in creating a state drought management plan.

ignore until it's too late. But the current drought has highlighted the need for planning to reduce drought impacts."

Meeting for more than a year now, volunteers representing various stakeholders, officials from the Georgia Department of Natural Resources and a research team led by Steinemann have discussed both the indicators and impacts of drought. They are also formulating strategic and tactical responses to drought. This information is the basis for a drought plan, which outlines actions to take before, during and after a drought.

"The plan links indicators, which characterize stages of drought severity, with responses," Steinemann explains. "For instance, when an indicator shows that a drought is developing, a response could be to curtail non-essential water uses. Then during a drought, the plan also provides guidance, such as when and how to make water use restrictions more stringent, or when and how to implement water use surcharges to manage demand. The idea is that it's more effective – and less painful – to prepare for drought, and take timely actions, than to wait until a full-blown crisis has developed."

Georgia's drought plan will first address drought at the state level, then at the regional or local level, such as river basins, water agencies of Georgia (for example, the North Georgia Regional Water Authority created by the General Assembly earlier this year), counties and municipalities. The plans would be linked to make drought management more consistent, yet each plan would still reflect unique local conditions, Steinemann explains. For instance, "odd-even" water use restrictions effectively reduce water use in some counties, but may actually increase water use in other counties.

"Our experience with drought has shown the need for a coordinated and comprehensive approach," Steinemann says. "How can we develop mechanisms to more efficiently share water, for example?"

Already, the DNR's Environmental Protection Division (EPD) requires water purveyors to develop drought management plans, but Steinemann found in her research that few of these are actually implemented or effective. Officials hope the new statewide plan will provide guidance for local and regional entities to tailor their plans to the type of drought, the users affected and the effects of various mitigation strategies on local users, as well as those elsewhere in the state.

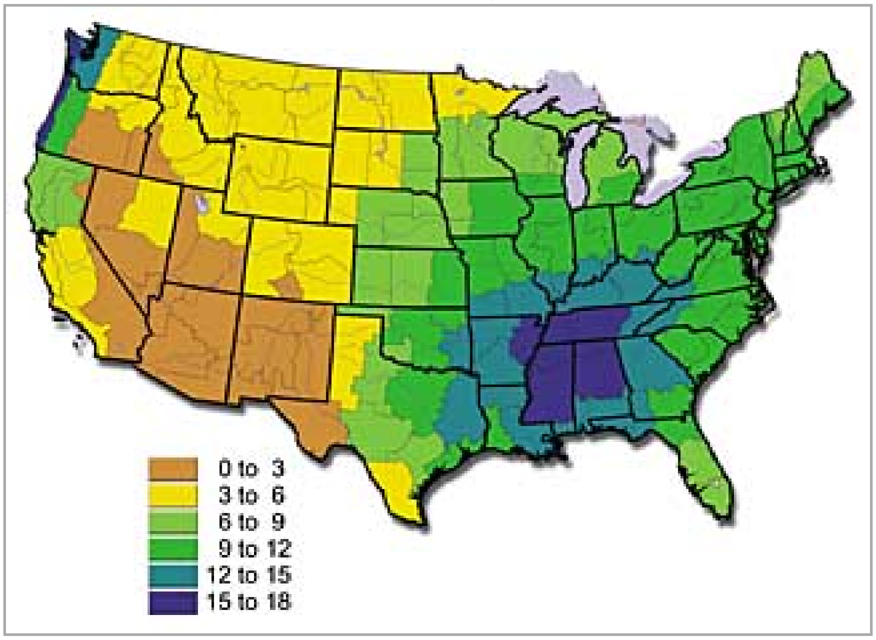
Georgia's plan is incorporating expertise gained from drought experiences in the state and elsewhere to identify three main types of drought and their indicators. They are meteorological, agricultural and hydrological. All droughts begin with a deficiency of precipitation, explains research team member Don Wilhite of the National Drought Mitigation Center.

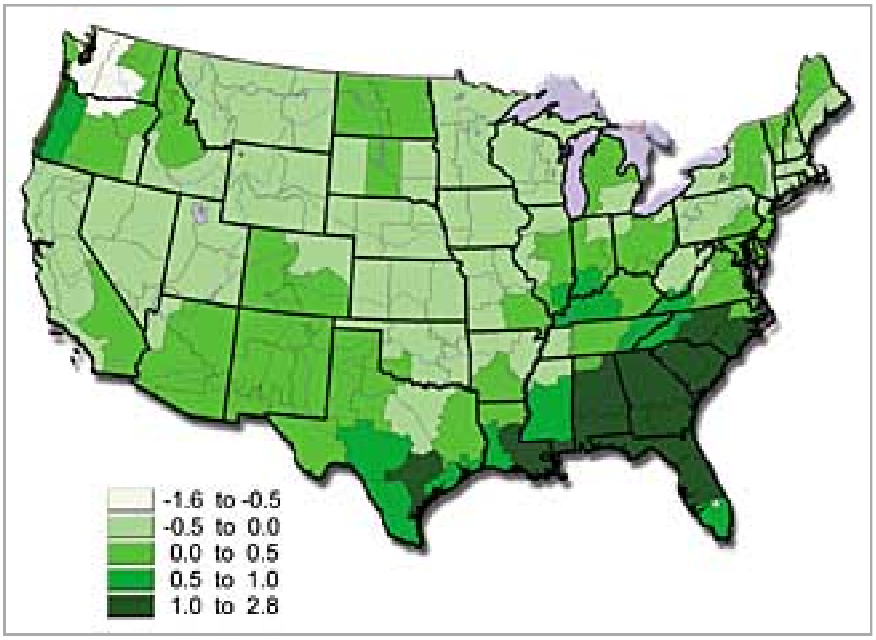
Meteorological drought occurs when there's a precipitation deficiency compared to normal levels over time. Agricultural drought is defined by available soil moisture – the principal factor affecting plant growth and yield. Hydrological drought is based upon surface and subsurface water supplies (i.e., reservoir levels, stream flow and groundwater).

"The drought plan we are developing in Georgia uses indicators of all of these types of drought to identify potential impacts and mitigation and response actions," Wilhite says.

To evaluate whether these actions would work in reality, the planners are conducting a "virtual drought" exercise, a simulation engineered by research team member Richard Palmer of the University of Washington. The other test for Georgia's drought plan is implementation, which the EPD could begin later this

maps courtesy of Bill Drummond





year.

"The plan should be implemented as a working document that is continually refined and updated with new information," Steinemann says. "I view the plan as a process, not just a product."

Drought planners need to know the accuracy of precipitation forecasts, such as the one above. City planning program Associate Professor Bill Drummond is taking forecasters' data and creating maps that show the "forecast advantage"; that is, how much closer the forecast was to the actual precipitation than the normal levels indicated by climatology. The map below is based on a forecast made in mid-October 1999 for the three-month period from December 1999 to February 2000. Drummond's work will provide meaningful climate forecast information to water managers to help them in decision making.

Beyond all the planning, many people agree that mindset changes must occur to ensure the success of a drought management plan.

At the individual level, Steinemann wants people to understand the consequences of their decisions on water use. She conveys this message to students in environmental education presentations she makes as part of her research funded by the National Science Foundation.

"For example, one of the major sources of non-point pollution, and even public health risks, is chemical applications to lawns," Steinemann says. "I introduce students to an alternative called xeriscaping, which uses more native vegetation to reduce the need for water, pesticides and fertilizers. Plus, xeriscaped lawns cost less to maintain.... It's a change of ethic. We have to begin to think about the impacts of our individual decisions."

Meanwhile, businesses and industries can make a difference by lessening their dependence on water, says Bob Kerr, who is leading DNR's drought planning. He also heads DNR's Pollution Prevention Assistance Division that communicates this message to industry groups and offers them technical assistance.

At the local government level, Steinemann hopes officials will understand the need for drought planning, particularly as population growth occurs. "Drought occurs when demands exceed supplies," she explains. "Demand for water has skyrocketed in Georgia, but new supplies are limited."

At the state level, officials are beginning to take a risk-management approach to drought management. "This is a slow process to change the historic way of doing things," Wilhite says. However, identifying the likely impacts of drought, and the factors behind that vulnerability, allows the state to address the risks associated with drought in advance. In time, these actions will lessen risks and therefore, impact the level of government intervention required in the form of emergency assistance."

The state is also determining what policy changes it needs to make regarding water allocation in the Southeast, says Kerr, who is Georgia's chief negotiator in the long-running "water wars" between Georgia, Alabama and Florida.

"When we look 30 to 50 years into the future, we see growth, and knowing the stress on the water supply today, we have to implement policies to protect water quality, wildlife management and other concerns," Kerr says. "We also have to be prepared to react when there is a drought. We want to avoid reacting in a crisis mode."

Steinemann is hopeful about the outlook for Georgia. "Now, we will be much better prepared for the future," she says. "Our drought experiences have accentuated the need for this plan."

For more information, contact Anne Steinemann, City and Regional Planning Program, College of Architecture, Georgia Tech, Atlanta, GA 30332-0155. (Telephone: 404-894-6491) (E-mail: anne.steinemann@arch.gatech.edu)

Research Horizons

Happy Motoring on Safer Interstate Highway

High-tech fog warning system developed at Georgia Tech will issue advisories to motorists.

By Jane M. Sanders

A HEAVILY TRAVELED, 14-mile stretch of interstate highway in south Georgia cuts through a peat bog, which often conspires with humid air to produce fog so thick it separates drivers from reality. Occasionally, the swamp hosts forest fires ignited by lightning, and southern breezes push gusts of smoke into the sightline of drivers.

image courtesy of Wayne Daley

GTRI research engineer Jack Wood checks one of the fog warning system's signs along I-75.

Many a motorist has entered the fog zone, often in the dark of night, and been taken by surprise; some have suffered injury and even death in vehicle pileups. One often-repeated story is that of a state trooper who encountered smoke and fog so thick, he could not see the blue light atop his patrol car as he stood at the hood of the vehicle.

State and federal highway officials decided several years ago it was time to make the roadway safer, but not just for the 22,000 motorists a day who pass through this often-treacherous area. It was time to help other drivers across the nation who fight fog, smoke, dust and blinding snow on the highways. They requested proposals for design of a state-of-the-art visibility detection and warning system.

Engineers at the Georgia Tech Research Institute in Atlanta proposed a solution, and this summer, a $2.4 million, automated fog and smoke warning system is expected to become operational on Interstate 75 near Adel, Ga., just 35 miles north of the Florida state line. Georgia Department of Transportation (GDOT) officials call it a model system that could be implemented wherever visibility problems regularly occur.

"We always had in mind that we were building a model system based on the original requests for proposals from the Federal Highway Administration and the GDOT," says GTRI project manager Gary Gimmestad. "We believe this system will improve safety in this area (near Adel), and we want it to be applied elsewhere."

At the heart of the system's data collection operation is a set of 19 commercially available fog sensors. Each sensor has a transmitter and a receiver. The transmitter is angled away from the receiver, so that in clear conditions, its light beam misses the receiver. But when fog or smoke particles are present in the air, they scatter some of the light into the receiver. The sensor detects this light and sends a reading to the system's on-site computer.

image courtesy Wayne Daley

GTRI researchers Marlon Moses and John Trostel check the operation of one of the fog sensors in the warning system along I-75 near Adel, Ga.

The computer, linked to the system's components via a fiber optic network, is located inside a concrete building alongside the interstate in the fog zone. The computer collects data not only from the fog sensors, but also from an adjacent weather station, speed detectors on the highway and television cameras, which GDOT officials can operate remotely to scan the area. Also, the computer contains several telephone modem lines so officials can remotely upload and download data from the site.

A team of GTRI researchers led by engineer Richard Carey designed the overall system layout, as well as its hardware and software. Technician Marlon Moses assisted with the hardware selection and the design of interfaces to the fog sensors, and power control and protection components. The fog sensors are descendants of airport visibility technology.

The system's software analyzes data from the fog sensors, notifies GDOT officials at the Transportation Management Center (TMC) in Atlanta of potential problems and automatically decides what message to post on four changeable message signs on the north- and southbound outskirts of the fog zone. The 36-foot-wide and 9-foot-high signs are attached to metal structures built over the highway.

When the fog warning system detects a decline in visibility to a certain level, it automatically notifies the TMC and also sends a caution to motorists via the changeable message signs. It also turns on streetlights along the roadway. If visibility drops to a second threshold, the system again notifies the TMC and then issues a speed advisory to motorists via the signs. The system recognizes two additional lower levels of visibility and again alerts the TMC and issues advisories to motorists to further decrease their speed.

TMC personnel will have a protocol for notifying local officials, who could put GDOT people on the scene at some point as the visibility gets worse.

"That is when the television cameras will be useful," Gimmestad says, "because they will give local GDOT people a visual impression of conditions at the scene."

In very poor conditions, local officials may decide to close the road and detour traffic, if this is warranted.

GDOT project manager Timmy Rowe believes the GTRI warning system will greatly enhance safety in the fog-plagued area. "Safety is the key," he says. "This has been a problem area for years, and we're hoping this system will improve safety."

image courtesy of Cindy Lane, GDOT

Contractors install the changeable message signs that will warn drivers of thick fog and poor visibility on a 14-mile stretch of I-75 in south Georgia.

GTRI researchers hope to conduct a follow-up study on the warning system after it becomes operational. "We want to study the system's maintenance requirements and accuracy," Gimmestad says. "We also want to look at human factors, such as whether drivers are really slowing down when they see warnings on the changeable message signs."

In designing the warning system, GTRI engineers found that various systems, usually simpler ones, have been in use since the early 1980s. The only other similar system in the United States is one on I-75 in Tennessee, but it is not an automated system. So the system near Adel is unique in this nation, though Europe is home to several automated warning systems, Gimmestad says.

The Adel system could be implemented elsewhere at a much lower cost because all of the design work is completed, GTRI project engineer Wayne Daley says. It would only require slight modifications of the software and hardware. The system could even be calibrated to detect dust or snow, rather than fog and smoke.

"The system near Adel is definitely going to attract more attention once it starts operation," Daley says. Indeed the researchers have already gotten inquiries from transportation departments in West Virginia, Alabama and Florida.

For more information, contact Gary Gimmestad, Georgia Tech Research Institute, Atlanta, GA, 30332-0834. (Telephone: 404-894-3419) (E-mail: gary.gimmestad@gtri.gatech.edu); or Timmy Rowe, Georgia Department of Transportation, 120 East By-Pass NE, Moultrie, Ga., 31768. (Telephone: 912-891-7130) (E-mail: timmy.rowe@dot.state.ga.us)

Faculty Profile

Claudia Huff brings energy and soul to Foundations for the Future.

By Gary Goettling

"I'm not an engineer, I'm not especially technical and I'm certainly not the smartest person in the group," Claudia Huff laughs with engaging modesty. "I work with a terrific group, and they're really the ones who make things happen."

She's talking about Foundations for the Future, a Georgia Institute of Technology project to assist Georgia K-12 educators in incorporating technology into their classrooms.

photos Gary Meek

Claudia Huff, center, leads Foundations for the Future, a Georgia Tech project to assist Georgia K-12 educators in incorporating technology into their classrooms. She purposely avoids descriptions like "boss" or "supervisor" because the 10-member Foundations for the Future core staff (meeting here) operates by consensus, instead of the traditional hierarchical model.

Huff has served as leader of the project, abbreviated as F3, since its inception five years ago. She purposely avoids descriptions like "boss" or "supervisor" because the 10-member F3 core staff operates by consensus, instead of the traditional hierarchical model. At a time when "team" is more often than not simply an overworked organizational buzzword, it truly applies to Foundations for the Future.

"We're all on a level playing field," says Dara O'Neil, an F3 staffer who has worked with Huff for 10 years at Tech on many different projects and considers her a mentor. "Everybody's input is valued, and decisions are not made without talking to each other about them.

"It's very much a nurturing environment," she adds. "The people who work on the team are selected for their ability to work that way."

Jim Demmers, also an F3 core team member, has known Huff for more than 25 years and considers her a close friend, as well as a co-worker. "She is very good about supplying the means and opportunities necessary for others to do their best work, without taking any of the credit for herself," he says. "This is what sets her apart from the majority – her willingness to share the glory, to shine by the reflected light of others."

Huff's abiding respect for colleagues and her insistence on sharing credit inspires strong loyalties not only among the staff, but helps motivate them for building upon F3's impressive achievements.

Foundations for the Future is dedicated to breaking down the so-called "digital divide" in Georgia that separates schools with access to the Internet's vast resources and those without electronic links. To date, the organization has worked with 25 city and county school systems, primarily in rural and inner-city areas of the state.

One aspect of F3 is the nuts-and-bolts work associated with installing network infrastructure or providing technical assistance.

A recent example is Elbert County, where almost every school was networked to the Internet. Because of circumstances dictated in part by geography and distance, one elementary school had been left out of the loop. F3 engineers devised a way to bring that school online.

Huff's background in proposal writing, honed while she was in graduate school, has proven to be invaluable for another facet of F3's mission, which is to help communities and schools win funding for technology development and implementation. F3 staff teaches the "ins" and "outs" of writing proposals and locating grant resources.

Among F3's accomplishments last year, Huff and her associates were instrumental in helping the DeKalb County School System secure a $1 million grant from the U.S. Department of Education to expand a Family Technology Resource Centers program.

"Claudia has a vision about taking schools from the one-room schoolhouse to the one-world classroom," says Dr. Mindy DiSalvo, director of the program, which is considered a national model. "She has given us great ideas about grant opportunities and how to better use our resources. She's one of the most dynamic and delightful people I know."

Over the past five years, F3 has helped school districts across Georgia secure more than $6 million in funding.

Student Scientists

Environmental education program has a global reach.

Researchers all over the world are learning a little more about the planet each day, thanks to a federal initiative that places thousands of K-12 students in the role of scientists.

The GLOBE program – Global Learning and Observations to Benefit the Environment – involves specially trained teachers who instruct their students in collecting a specific set of data and uploading that information to the Internet.

photo by Gary Goettling

Sixth-grade students Tina Vuncannon, left, and Kyle Staley measure rainfall and temperature at Brockett Elementary School's GLOBE station in Tucker, Ga.

Since 1997, the Georgia Institute of Technology's Foundations for the Future (F3) has been one of the organizations training teachers in the GLOBE protocols. The program is designed to help students boost their skills in science and math, while providing hands-on environmental education.

"It's a 'train the trainer' kind of activity," says Claudia Huff, a Georgia Tech Research Institute researcher who helps coordinate F3's partnership with GLOBE. "The week-long training is quite

A third aspect of F3's activity is professional development. Through a monthly gathering called the Explorers Guild, teachers come to Tech to learn how to take advantage of information technology. Topics range from how to use several forms of connectivity and Web-page design to basic Internet how-to instruction.

"The level of discomfort among teachers with regard to computers is still way too high for us as a nation," Huff says. "That's why the training we provide includes a lot of hand-holding."

Huff's exceptional people skills, which serve her so well with the F3 team, are equally advantageous in dealing with clients she encounters from all walks of life.

"She's a born facilitator and can pretty much carry on an intelligent conversation with just about anyone on any subject – even when she's not all that familiar with the topic," Demmers laughs. "She's able to do this because she's such a great listener and enabler. I've always been impressed with her optimism and joie de vivre."

Huff's empathy for others grew during her college days. A graduate of Indiana University with a degree in social science, she made the unusual – for a white person – move of enrolling at Atlanta University for a master's degree in Afro-American studies.

"I lived in the dorm and spent just about all my time on campus. It was a very immersive kind of experience," she says. "I had a terrific time, worked with some wonderful people and at the same time picked up a lot of insight and understanding.

"I learned to see the world from a different perspective, through other people's eyes," she explains. "When you put yourself in someone else's shoes and try to understand their perspective, you realize that truth isn't necessarily what you thought it was. If someone else perceives the world differently, that perception is what matters to that person."

Independent thinking is a carry-over trait familiar to those who work with Huff.

"It speaks to Claudia's rebellious nature that she's willing to challenge the accepted protocols and nuances of working in an academic environment," O'Neil says. "Things that people take for granted and think can't be changed, she'll try and change them."

intense. Teachers spend a lot of time in the field -- literally -- collecting data, making observations and learning the proper data-collection procedures. They also work on computers to learn how to add their data to the GLOBE site."

By providing comprehensive teaching skills, F3 develops committed, effective GLOBE teachers throughout Georgia. Those teachers can help more students benefit from the education program.

A network of 10,000 schools in 90 countries is involved in GLOBE. At each participating school, students collect a certain category of data daily at solar noon and log the information at the password-protected GLOBE Web site. Some schools may measure soil characteristics in a defined area, while others gather meteorological information.

Metro Atlanta's DeKalb County School System, whose teachers have received GLOBE training for the past several years, boasts several GLOBE participants. At Brockett Elementary in Tucker, Ga., for example, a band of Discovery class students maintains an outdoor weather station equipped to measure rainfall and temperature maximum and minimum readings over a 24-hour period. The students also note the type of cloud cover at data collection time. The information is immediately uploaded to www.globe.gov, where Brockett's contribution to the mosaic of atmospheric readings from schools around the world is accessible to scientists studying climate and other environmental activity.

"The students are pretty diligent about taking the measurements each day," says Brockett teacher Janie Cohen-Legge. "They have a schedule, and their commitment to following it is a useful lesson by itself. Logging their data and observing the changes taking place over time is a terrific hands-on experience for them in environmental science."

In upcoming months, F3 will focus on improving its teacher training by ensuring a closer fit between GLOBE protocol requirements and the state's Quality Core Curriculum mandate. F3 has also started offering refresher training and is pursuing partnerships with other institutions to enhance the resources available to GLOBE teachers.

"We've also been doing a lot of mentoring and support to keep the level of data collection high," Huff says. "It's a great program that brings together a lot of science skills. A great way to learn science is by doing science. Perhaps best of all, it guides students in using the Internet in a meaningful way."

— Gary Goettling

O'Neil offers the example of state funding for F3, which conventional wisdom held to be a waste of time and energy. Huff went ahead anyway with a tenacious development effort that resulted in a $278,000 allocation from the General Assembly.

"Not taking 'no' for an answer is very much a Claudia trait," O'Neil observes.

The mother of an 11-year-old daughter, Hilary, and wife of Bill Riall, a principal research associate at the Economic Development Institute, Huff joined the Georgia Tech staff in 1983 as a research associate after several years in the private sector. Her activities have embraced energy conservation, international work and economic development.

"I've done a lot of things related to technology transfer and now, with Foundations for the Future, telecommunications, which is just another form of tech transfer," she says.

In addition, she is a principal research associate at GTRI's Electro-Optics, Environment and Materials Laboratory and a member of the faculty of the Test and Evaluation Research and Education Center. She is also serving a three-year term on the GTRI Fellows Council. But her primary focus remains the task of augmenting education in Georgia through Foundations for the Future.

"This is a great way to make a living," Huff says. "It's important work that's worth doing, and it's the kind of thing people look to Georgia Tech for, which is technological expertise."

For more information, contact Claudia Huff, Georgia Tech Research Institute, Atlanta, GA 30332-0837. (Telephone: 404-894-3941) (E-mail: claudia.huff@gtri.gatech.edu)

Research Horizons

Immersed in a Virtual World

Researchers using virtual reality technology for therapy and other applications.

By Jane M. Sanders

IN TODAY'S AGE of cyberspace, it may not surprise some that people with mental health problems are finding help in a virtual world.

But it was a decade ago when Larry Hodges first envisioned the potential of a computer-generated virtual world for treating people with anxiety disorders. Today Hodges, a professor in the Georgia Institute of Technology College of Computing, is enjoying academic and business success with his collaborator Barbara Rothbaum, an Emory University psychiatry professor. Most important to them, they say, is helping real people deal with real problems in a virtual world.

photo by Gary Meek

Fear of public speaking is one of several phobias that clinicians can treat with virtual reality therapy. Virtual environments created by Georgia Tech and Emory University researchers are being used at psychologists' offices in Atlanta and 12 other locations nationwide. (300-dpi JPEG version - 202k)

"Virtual reality technology works well in treating a number of conditions," Hodges says. "We can use it when treatment is too difficult to handle logistically in reality, or it's too time consuming. Also, we ask whether it's too dangerous to treat something in a real environment."

photo by Gary Meek

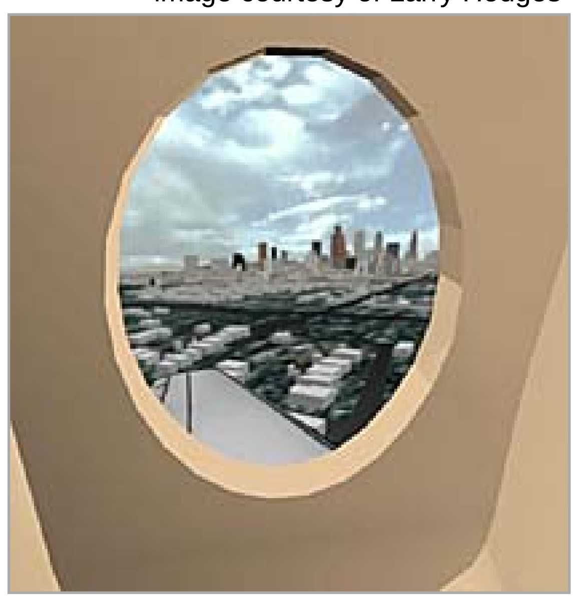
Larry Hodges, a Georgia Tech professor of computing, collaborated with Barbara Rothbaum, an Emory University professor of psychiatry, to create virtual environments to treat a variety of phobias, including the fear of flying.

For example, therapists have traditionally treated the fear of flying in an airplane by exposing the patient to a real aircraft and eventually a flight. Logistically, it is difficult to arrange such exposure. Emotionally, it is difficult on the patient because of potential embarrassment. So only a small percentage of people with a fear of flying have sought treatment.

But now the 15 million Americans who are afraid to fly may be more willing to undergo therapy. In the privacy and convenience of a therapist's office, they can face their fear on a virtual airplane – one of six virtual therapy environments created by Hodges and Rothbaum and marketed by their Atlanta company, Virtually Better Inc.

In a darkened treatment room, the patient wears a head-mounted display with earphones and separate screens for each eye. The display also includes a head-tracking device to provide location and orientation information to the therapist's computer in the room. The computer then provides visual images on the screen that are consistent with the direction in which the patient is looking in the virtual environment.

image courtesy of Larry Hodges



The patient is seated in an armchair on a low platform and buckled in with a seatbelt. The chair vibrates, similar to an airplane seat, as the virtual aircraft takes off and lands. The patient hears the roaring of the plane's engines as they accelerate. Looking out the window, the patient sees the skyline of Atlanta fade in the distance as the aircraft takes flight. The therapist assumes the role of pilot, and the patient hears his voice announcing the departure.

Though the virtual reality (VR) graphics are simple, they combine with the auditory and tactile stimuli to create an environment real enough to immerse patients in their surroundings.

"It gave me an impression of the environment of the airplane cabin and the window view," says Shannon, a 38-year-old who was successfully treated at Virtually Better in 1999. "At first I was disappointed that it was not more realistic. But then the chair began to vibrate, and I buckled the seatbelt.... So eventually the entire environment combined to set me up for a representative experience."

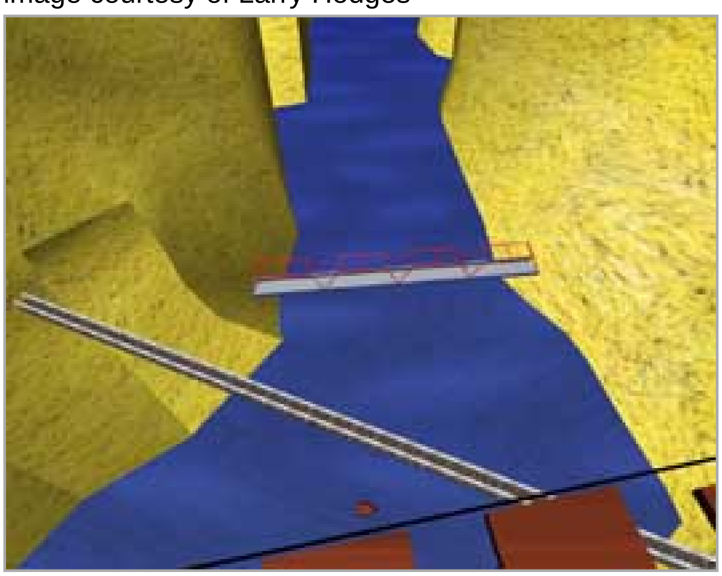
The 15 million Americans who are afraid to fly may be more willing to undergo therapy now that a new kind of treatment is available. In the privacy and convenience of a therapist's office, they can face their fear on a virtual airplane created by Georgia Tech and Emory University researchers. Here is a view from the airplane's virtual window. (300-dpi JPEG version - 120k)

VR therapy promises to be an effective treatment, particularly for the fear of flying, the researchers say. Their controlled study of patients undergoing VR therapy for a fear of flying showed the virtual method works as well as traditional exposure therapy. The researchers reported their findings last year in the *Journal of Consulting and Clinical Psychology*.

Furthermore, patients seem to prefer virtual therapy over the traditional treatment, Hodges says. All but one of the control patients, who did not receive therapy during the study, later chose to undergo VR therapy instead of traditional exposure therapy.

"Over the course of treatment, my level of fear decreased from extreme to manageable," Shannon says. "I used the fear management techniques I learned in the first four sessions and then practiced them in the VR environment.... I started off doing badly, but I progressed dramatically over the course of the therapy."

image courtesy of Larry Hodges



Shannon loved to fly as a child, but then had a bad experience on a flight as an adult. She became disoriented and fearful as her airplane was forced to circle Atlanta's Hartsfield Airport in heavy clouds before it could get landing clearance. For the next eight years, she flew only when she absolutely had to do so; flying induced panic attacks. Now, after VR therapy, Shannon says she has rediscovered the fun of flying that she experienced as a child.

In addition to fear of flying, Virtually Better Inc. now offers VR

Gradual exposure to the view from several virtual bridges can help patients deal with a fear of heights. (300-dpi JPEG version - 386k)

therapy programs for fears of heights, storms and public speaking. VR therapy initially proved its effectiveness for treating fear of heights in 1993 when Hodges and Rothbaum conducted the first controlled study on the use of VR exposure for treating an anxiety disorder. They published their groundbreaking results in the April 1995 issue of the *American Journal of Psychiatry.*

Another effective VR therapy program licensed by Virtually Better is Virtual Vietnam, which treats veterans suffering from post-traumatic stress disorder. It continues to be successfully used at Veterans Administration hospitals in Atlanta and Boston.

Virtually Better operates a VR therapy clinic in metro Atlanta, and it has licensed its programs to 12 other clinical psychology practices across the United States. Therapists can install a complete system for $15,000. Treatment costs range from $100 to $200 a session, and the therapy usually requires seven to 15 office visits. Many insurance companies will cover the cost of VR therapy now because it is considered a form of the long-proven exposure therapy.

"The need for VR therapies for anxiety disorders is large," Hodges says. He quotes statistics from the American Journal of Psychiatry and the U.S. Census that indicate more than 30 million Americans between the ages of 15 and 54 suffer from some type of anxiety disorder.

image courtesy of Larry Hodges

VR therapy initially proved its effectiveness for treating the fear of heights in 1993 when Georgia Tech and Emory researchers conducted the first controlled study on the use of VR exposure for treating an anxiety disorder. Patients rode a virtual glass elevator to the top of the atrium in a virtual hotel. (300-dpi JPEG version - 167k)

To meet the demand, researchers at Georgia Tech, Emory, Virtually Better and elsewhere are developing additional virtual environments for therapy and other purposes. Chris Shaw, a visiting senior research scientist at Georgia Tech, is developing a program for treating people with a fear of driving. Eventually, patients will wear a head-mounted display and hold onto a steering wheel and press gas and brake pedals. As they steer and accelerate or brake, they will first go through a virtual parking lot, then later a virtual highway.

Virtual environments can serve other purposes, as well. Emory University graduate student Jon Gershon, who works for Virtually Better, is studying the use of VR for pain distraction in pediatric cancer patients at Egleston Children's Hospital in Atlanta. In the privately funded study, patients undergoing catheterization for chemotherapy wear a head-mounted display and interact with a Georgia Tech and Zoo Atlanta educational VR program called Virtual Gorilla.

One patient consistently vomited in anticipation of the procedure; the only time she didn't throw up was when she was interacting with the Virtual Gorilla program, Hodges recalls.

"This is probably one of those things that will be difficult for a hospital administrator to show on the bottom line how VR for pain distraction saves them money," Hodges says. "The real value here is to the kids, the parents, and the nurses and doctors who treat them. It's hard to put a price tag on that. But this is an important part of what we do with VR.... I think eventually that hospitals will have these systems because private foundations and children's advocacy groups will provide them."

Researchers elsewhere are also beginning to use VR technology in assessment, diagnosis and physical rehabilitation. For example, researchers at the University of Southern California are creating a virtual environment to assess children for attention deficit hyperactivity disorder. Children will wear a head-mounted VR display depicting a virtual classroom. Clinicians can control the environment and more objectively analyze the patient's responses, Hodges says.

image courtesy of Larry Hodges

Another venue for VR technology is in training and evaluating employees. Shaw is creating a virtual house fire for the Atlanta Fire Department to train and evaluate officers for promotion. The virtual fire could help determine whether officers know how to fight a fire, manage people and keep firefighters as safe as possible on the scene, Shaw explains.

Also, the house fire scenario is especially important because officers in some areas – for example in the bustling highrise district of Midtown Atlanta – don't often fight this type of blaze.

Virtual Vietnam is a VR therapy program that treats war veterans suffering from post-traumatic stress disorder. Created by Georgia Tech and Emory University researchers, Virtual Vietnam is being used successfully used at Veterans Administration hospitals in Atlanta and Boston. (300-dpi JPEG version - 317k)

"They want everybody to be exposed to all types of emergencies," Shaw says. ".... So we are developing scenarios in the program where officers can make good choices and not good choices. The simulation will allow opportunities for many choices to be made."

Still other applications for VR technology are in education, national defense, design and scientific visualization. Georgia Tech researchers are active in all of these areas.

VR technology has existed since the early 1970s, and it has come a long way, particularly because of advances in computing power. Still, there are many technical hurdles for researchers to jump. For example, it is limited by tactile feedback, hand-eye coordination and the creation of smell, Hodges says.

"VR barely works, but it is actually useful and cost-effective, particularly for therapy," Shaw says. "The cost for a VR system has dropped considerably. And 3D graphics are cheap now because of gaming applications.... So VR is starting to work in situations where you can't easily adjust reality."

As costs continue to decrease and the technology improves, and as more studies show success with VR therapy and other applications, VR technology will become more widely used, Hodges adds.

For more information, contact Larry Hodges, College of Computing, Georgia Tech, Atlanta, GA 30332-0280. (Telephone: 404-894-8787) (E-mail: hodges@cc.gatech.edu); or Chris Shaw, same address. (Telephone: 404-894-6328) (E-mail: cdshaw@cc.gatech.edu); or Barbara Rothbaum, Department of Psychiatry and Behavioral Sciences, Emory University School of Medicine, 1440 Clifton Road, Atlanta, GA, 30322. (Telephone: 404-778-5684) (E-mail: brothba@emory.edu); or Virtually Better Inc., 2450 Lawrenceville Highway, Suite #101, Decatur, GA 30033. (Telephone: 404-634-3400) (Web site: www.virtuallybetter.com)

Research Horizons

Another Antarctic Atmosphere Surprise

Scientists find evidence of highly oxidizing environment over the South Pole.

By Jane M. Sanders

MORE THAN 15 YEARS after the discovery of an ozone hole in the stratrosphere over the Antarctic, the remote continent is yielding another atmospheric surprise.

A team of researchers led by the Georgia Institute of Technology has found a surprisingly high level of an air-purifying chemical (or oxidizing agent) in the near-surface atmosphere over the South Pole. The finding has implications for interpreting historical global climate records stored in Antarctic ice cores.

image courtesy of Doug Davis

A team of researchers led by the Georgia Institute of Technology measured atmospheric trace gases and aerosols while working from NOAA's Atmospheric Research Observatory at the South Pole. They found a surprisingly high level of an air-purifying chemical called the OH radical in the near-surface atmosphere over the pole. In the foreground is a meteorological tower on which scientists recorded measurements of temperature, wind speed and nitric oxide at five different elevations. (300-dpi JPEG version - 336k)

The summertime 24-hour average value of the primary atmospheric oxidant – known as the hydroxyl (OH) radical – at the South Pole is higher than that estimated from OH measurements recorded at the equator. The researchers will report their findings this summer in the journal *Geophysical Research Letters*. The OH radical is widely recognized as vital to scrubbing pollution and naturally occurring chemicals from the air throughout the globe; it prevents a buildup of toxic levels of these substances.

"What we now know is that the near-surface atmospheric zone called the mixed layer (from the surface upward to between 20 to 200 meters) is a highly oxidizing environment at the South Pole," says Doug Davis, one of the lead researchers and a professor in the Georgia Tech School of Earth and Atmospheric Sciences. "Equally exciting, we are beginning to see evidence that a lot of this oxidizing chemistry is also occurring down in the snowpack. Thus, once things get buried in the snow, there continues to be active chemistry – including oxidation – that could further modify chemical species before they are trapped in the ice in their final chemical forms."

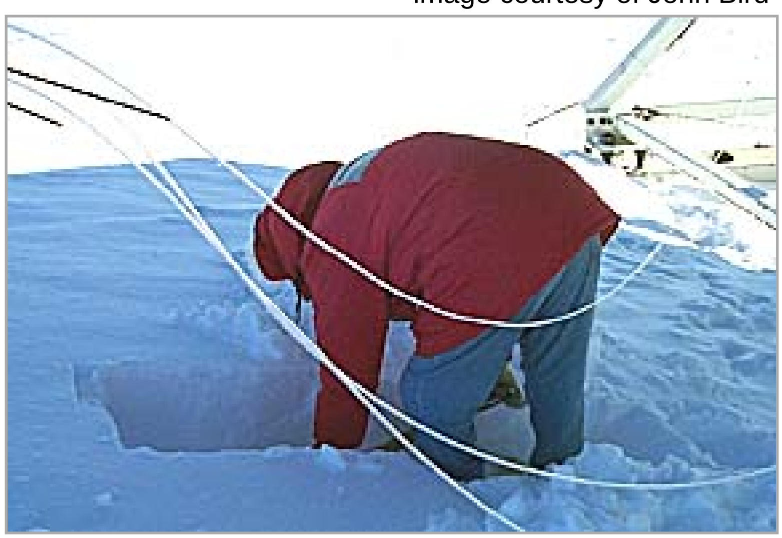
This finding suggests that glacio-chemists – who study climate change based on an analysis of trace chemicals trapped in polar ice – have to be far more careful in their interpretation of Antarctic ice cores, says Davis, whose research team is funded by the National Science Foundation. Changes in some chemical species buried may continue for another five to 10 years after they are trapped in the snowpack. Davis expects that scientists will soon focus more attention on this topic.

"Snow release of nitric oxide, which leads to the formation of OH, can in principle occur anywhere globally where there are accumulations of nitrate ions in ice and there is also solar radiation," Davis says. "Other researchers have found evidence of this phenomenon in Summit, Greenland, and Alert, Canada. What makes the South Pole unique is that the levels of nitric oxide and other nitrogen oxides are nearly an order of magnitude higher than anywhere else.

"But any significant elevation of nitric oxide at any snow-covered location should result in an enhancement of OH," Davis adds. "And, anytime you are producing higher levels of OH, it means this chemistry is having some local or regional impact. The final global impact from this chemistry, however, is still unknown."

At the South Pole, researchers recorded OH radical levels over a 24-hour period; the average measurement was about 2 X 106 molecules per cubic centimeter of air several days during their December 1998 to January 1999 expedition and again from December 2000 to January 2001. These measurements are nearly an order of magnitude higher than what they originally expected to find based on their

image courtesy of John Bird



Antarctic coastal measurements of nitric oxide, Davis says.

Doug Davis, a Georgia Tech professor of earth and atmospheric sciences, was one of the lead researchers for the NSF-funded ISCAT study at the South Pole. Here, he's shown digging a snow pit in front of the Atmospheric Research Observatory to measure nitric oxide, nitrogen dioxide and ozone at different depths below the snow's surface. (300-dpi JPEG version - 327k)

To measure OH, the scientists used the selected-ion chemical-ionization mass spectrometer (SICIMS) technique, which in the early 1990s became the first sensitive method for measuring this radical. Georgia Tech Adjunct Professor Fred Eisele, the other lead researcher for this project, developed the SICIMS technique at Tech. Eisele is also a senior research associate at the National Center for Atmospheric Research in Boulder, Colo.

To measure nitric oxide (NO), researchers used the well-established chemiluminescence technique with modifications to improve its sensitivity by an order of magnitude. Nitric oxide, also a radical, is a byproduct of internal combustion engines. But Davis and his co-workers believe NO is formed at the South Pole when ultraviolet radiation interacts with nitrate ions. Scientists are not certain about the source of the nitrate, but it could originate from stratospheric denitrification processes and the long-range transport of nitric acid formed at low latitudes during electrical storms.

Although the factors that cause NO levels at the South Pole to exceed 550 parts per trillion by volume of air (pptv) are still under investigation, Davis believes the most important factor is the atmospheric mixing depth at the South Pole. This depth seems to be highly variable at the pole and is sometimes no more than 25 meters above the surface. The Davis team's latest results indicate large fluctuations in atmospheric levels of NO without major changes in NO levels within the snowpack.

Elevated levels of NO (20 to 550 pptv) in the near-surface atmosphere react with the hydroperoxyl radical – a less reactive oxidizing agent than OH – and are converted to OH and nitrogen dioxide. The latter reacts with OH to produce nitric acid, which can return to the snow, thus forming a closed cycle.

"It's not that this is new chemistry," Davis explains. "Most of the time in the background remote atmosphere where NO levels are typically less than 10 pptv, a large fraction of the hydroperoxyl radical reacts with itself and creates hydrogen peroxide, which is lost to the surface. But at the South Pole, in the presence of this large source of nitric oxide, the hydroperoxyl radical predominantly reacts with NO to generate the more reactive OH radical. Everybody tends to associate nitric oxide levels with combustion, thus the South Pole is one of the last places on earth that you might expect to find nitric oxide in such large concentrations."

Davis and his colleagues discovered the high NO and OH radical levels in their funded research project to study sulfur chemistry. The project, called ISCAT, for the Investigation of Sulfur Chemistry in the Antarctic Troposphere, began in 1994 with an expedition to Palmer Station on the Antarctic Palmer Peninsula. Specifically, the scientists are working to more fully understand the oxidation of dimethyl sulfide (DMS) under the cold conditions and high latitudes of Antarctica. This information will also help glacio-chemists better interpret sulfate and methane sulfonate concentrations incorporated into the continent's 400,000-year-old ice records, Davis says.

image courtesy of Doug Davis

This dome marks the entrance to Amundsen-Scott Station, the main U.S. facility at South Pole. The National Science Foundation has supported this facility, built more than 20 years ago. But accumulating snow has slowly buried the station, and it is now being replaced with a new, much larger structure. (300-dpi JPEG version - 228k)

Sulfate is a chemical signature for both southern hemispheric volcanic activity and major fluctuations in phytoplankton populations in the Southern Ocean that surrounds Antarctica. Phytoplankton lead to the release of DMS from the ocean, part of which is oxidized by OH to sulfate. Methane sulfonate is formed only from DMS.

Antarctic ice cores have revealed clear evidence of major volcanic activity in the Southern Hemisphere, and together with methane sulfonate, evidence of glacial and interglacial periods in the earth's climate history. The level of DMS is a chemical indicator of biomass production in the Southern Ocean, which, in turn, reflects both water temperature and solar radiation, Davis explains. So a more comprehensive understanding of DMS chemistry around and on the Antarctic should provide valuable information in studying past climate changes, he adds.

Based on the results of the sulfur chemistry studies led by Eisele and former Georgia Tech Research Institute scientist Harald Berresheim at Palmer in 1994, Davis and his colleagues moved their ISCAT research to the South Pole. They expected to record significant atmospheric transport of sulfate and DMS from the coast to the pole, which is 10,000 feet above sea level.

"Well, our initial hypothesis was wrong, and we found out why when went to the South Pole," Davis explains. "There was very little unreacted DMS that reached the South Pole because of the very high levels of OH in the near-surface air at the South Pole – and perhaps more importantly – over the entire polar plateau."

Elevated NO maintains a highly oxidizing environment on the polar plateau 24 hours a day, Davis says. The OH radical oxidizes most of the DMS before it reaches the South Pole.

"The oxidizing environment at the South Pole is truly astounding," Davis says. "We didn't expect it. And, initially, it made no sense. Nobody had the foggiest notion what was going on.... It was like finding some distant planet's atmosphere plugged into Earth's atmosphere, but having it limited to only the Antarctic polar plateau."

The researchers hope to make more sense of their data as they analyze measurements from their 2000-01 trip during the next year. Already, Davis' colleague, Associate Professor Greg Huey, may have identified a new atmospheric nitrogen oxide species in the Antarctic troposphere. Other institutions represented in the ISCAT team are the National Center for Atmospheric Research, New Mexico State University, the University of California at Irvine, Drexel University, the University of Minnesota, the University of New Hampshire and Arizona State University.

For more information, contact Doug Davis, School of Earth and Atmospheric Sciences, Georgia Tech, Atlanta, GA 30332-0340. (Telephone: 404-894-4008) (E-mail: douglas.davis@eas.gatech.edu); or Fred Eisele, National Center for Atmospheric Research, P.O. Box 3000, Boulder, CO 80307-3000. (Telephone: 303-497-1483) (E-mail: eisele@ucar.edu)

Research Horizons

America's Auto-Dependent Urban Form

Researchers in Atlanta studying land use and transportation alternatives to decrease traffic congestion and improve quality of life.

By Jane M. Sanders

OUT OF ATLANTA'S CHALLENGE to reduce traffic congestion and air pollution is emerging a comprehensive new study to determine what types of land use and transportation investment policies have the best chance to reduce auto dependence.

With that goal in mind, researchers at the Georgia Institute of Technology are also hoping to find solutions that promote economic, environmental and individual health in the study region of metropolitan Atlanta.

photo by Stanley Leary

"We want to have a better understanding of the implications of how land use and transportation investment practices converge to ultimately affect our mobility, our time use patterns, quality of life, our health and our air quality," says Larry Frank, an assistant professor of city planning in the Georgia Tech College of Architecture.

Frank is leading a detailed survey project that for the first time integrates travel and health information into one study. He says the study is creating a model and methodology that researchers can apply to other cities.

In this study, called SMARTRAQ – which stands for Strategies for Metropolitan Atlanta's Regional

Transportation and Air Quality – residents of 8,000 metro Atlanta households are voicing their opinions in several activity-based surveys. "That means we are capturing over a two-day period a snapshot of how people use their time," Frank explains.

Atlanta's rush-hour traffic often snarls on the downtown connector highway. Results from Georgia Tech's SMARTRAQ study will shed light on transportation investment policies that have the best chance to reduce auto dependence.

photo by Stanley Leary

Larry Frank, an assistant professor of city planning in the Georgia Tech College of Architecture, is heading the SMARTRAQ study.

The surveys began earlier this spring and will continue through the end of the year. Data analysis will take most of next year. Then policymakers plan to use the study results to plan transportation initiatives that may reduce traffic congestion in the region.

The $4 million project is sponsored by the Georgia Department of Transportation (GDOT) and the Georgia Regional Transportation Authority (GRTA), which also granted $1.3 million to the Atlanta Regional Commission (ARC) to hire a survey firm. Other organizations have also supported parts of the project; they include the Centers for Disease Control and Prevention (CDC), the Environmental Protection Agency, the Turner Foundation and the Metro Atlanta Chamber of Commerce.

This spring, the Texas-based survey firm NuStats began recruiting survey participants at random from five residential density categories – ranging from up to two residences per acre to more than eight per acre – in the 13-county metro area. Researchers are collecting demographic information and asking survey participants to complete a two-day travel and activity diary, a household and vehicle survey, and a personal survey. The diary will chart activities that require travel. The surveys will gather information and opinions on issues such as residential choice and public transportation.

Researchers believe many residents will gladly cooperate because it could affect their future. "The real benefit gained from participating is having your voice heard," says Heather Contrino, research director for NuStats. "This data will be used directly by ARC, GRTA and GDOT to support informed planning and decision-making."

Researchers are making a concerted effort to recruit participants that are traditionally under-served and hard to reach; these include low-income households, African Americans, Hispanics and Asians, explains SMARTRAQ researcher Jim Chapman. Members of Atlanta's environmental justice community have assisted researchers by evaluating survey materials and protocols for recruiting participants.

photo by Gary Meek

Workers and residents of Midtown Atlanta often walk to lunch and work to get exercise and avoid traffic jams. A Georgia Tech-based transportation study called SMARTRAQ will track such travel behavior.

Some of the study participants will also be recruited into one of three sub-surveys. A group of 1,500 will complete more detailed surveys about their attitudes and preferences for residential location. "Basically, that will define the market for less auto-dependent development patterns," Frank explains.

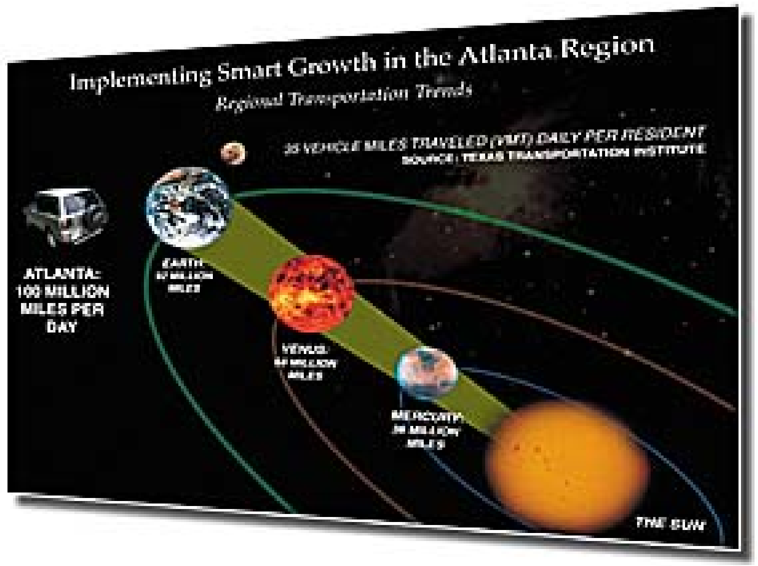
The other two sub-surveys are technologically supported with Global Positioning System (GPS) equipment. A group of 1,100 participants will have GPS devices installed in their vehicles so researchers can accurately track miles traveled. They will compare the GPS data with travel diary information to create "error correction factors or ways that help overcome any bias in the way data is collected," Frank explains.

The third sub-survey tracks physical activity. A group of 1,000 households will complete a health survey and physical activity diary. The survey will ask, for example, how active they are, how they feel, what their attitudes are about walking and bicycling, what factors they perceive as impairing them from physical activity and the level of social interaction within their communities.

"This information will be an umbrella for two sub-surveys," Frank explains. "Five hundred households will be equipped with Palm Pilots and handheld GPS devices. The Palm Pilots will serve as electronic diaries, so we will be testing the ability to collect this data electronically.... The Palm Pilot will be hooked to the GPS device, so if a participant reports going to the store, we'll know exactly how far they walked, how fast they walked, etc."

Another 500 participants will be equipped with accelerometers, which measure rate of motion, and researchers can convert that measure to caloric consumption. These devices are widely used by the CDC throughout the world. Participants will wear the devices during the two-day survey period while they are completing a travel diary.

illustration courtesy of Larry Frank



Atlantans travel an average of 35 miles a day, according to a study by the Texas Transportation Institute. View larger version (41k).

Results of the SMARTRAQ study may shed light on Frank's earlier finding from research in Seattle and Atlanta suggesting that the more interconnected, compact and inter-mixed development is, the less auto-dependent and more physically active its residents are.

"We need places that have proximity to complementary uses – where we live, work and play, or at least two of those," Frank explains. "But it's not just closeness, you also have to have connectivity.... Often, people live at the end of the cul-de-sac, while just over there through the woods and the ravine is commercial development, but you can't get there without driving.... We've created an irrational approach to using our land that requires us to use our cars. That means there is usually 'a cold start' of the car, which is highly polluting travel, to go just a short distance. Yet that distance is walkable."

Frank suggests that one option might be for neighborhoods to work with local governments to build sidewalks through the end of cul-de-sacs to adjacent commercial developments. In return, local governments could buy a parcel of land in or adjacent to the neighborhood and give residents a park where they can become more physically active.

Perhaps even before this strategy is implemented, the issue of connectivity between where people work and shop or eat lunch should be addressed, Frank says.

"It really is an added burden and expense when people have to leave work in the middle of the day to drive to lunch or the Post Office," Frank says. "I believe we can get people comfortable with this concept of connectivity by first making our employment centers more walkable. We have to ease into this change. So you go to a place like Perimeter Center (near I-285 on the north side of Atlanta) and invest money to retrofit it to make it more walkable. Then people become more comfortable with it. Then more high-density residential can be attracted into those areas."

Frank believes the SMARTRAQ surveys will show that many people are interested in living in a high-density residential area. They want to be near good schools, parks, shops and services, Frank says.

"But people in metro Atlanta have traditionally traded off living closer to their jobs for having reasonable schools, a comfortable home and spending a lot of time in their cars," Frank says. "So my hypothesis is that there is a latent demand for a less auto-dependant urban form. There is a potentially big market out there."

Ideas such as these are part of a SMARTRAQ effort to educate policymakers, developers and individuals about the consequences of their decisions, says researcher Peter Engelke. Among SMARTRAQ's efforts are staff presentations to interested groups, a newsletter, Web site (www.smartraq.net) and a "lessons learned" guidebook related to smart growth.

Innovative land use and transportation investment practices could stem from SMARTRAQ as policymakers begin to use the study results. For example, the Atlanta Regional Commission will use SMARTRAQ data to update its travel models and create a new, multi-year Regional Transportation Plan (RTP) for the Atlanta area. The RTP is the principal tool used in revising the region's annual Transportation Improvement Program (TIP), explains Charles Fleming, technology information director for GRTA. The TIP is a list of transportation projects that must be approved by state and federal officials.

In addition, the ARC will match SMARTRAQ survey data with land use data to develop models for its Livable Centers Initiative (LCI). The LCI is a multi-year, $350 million effort to develop "livable centers" in the region. SMARTRAQ data will help planners understand how various land uses and transportation investments will affect travel in and around livable centers, Engelke explains.

photo by Gary Meek

Palm Pilots and handheld Global Positioning System units will help researchers track travel patterns of some participants in Georgia Tech's SMARTRAQ transportation study.

"This is a new way of doing things," Fleming says of SMARTRAQ. "We are borrowing from the best practices across the nation and taking it to the next level to meet regional needs."

Thomas Galloway, dean of Georgia Tech's College of Architecture, also believes SMARTRAQ is breaking new ground. "Certainly, no metropolitan area of the U.S. today is as advanced in its thinking regarding the dynamics of mobility, land use, air quality and health as is revealed in the SMARTRAQ study," Galloway says. "This project holds great potential significance for Atlanta and areas like it that are facing similar problems."

With models built from the more accurate data that SMARTRAQ will yield, policymakers can make their decisions based upon a better informed balance of social, economic and environmental factors, says George Boulineau, a former GDOT director of planning and programming who now works part time for GDOT overseeing SMARTRAQ.

"Ultimately, we hope to reduce vehicle miles traveled and, in turn, reduce pollution in the form of ground-level ozone," Boulineau says.

> **For more information,** contact Larry Frank, College of Architecture, City Planning Department, Georgia Tech, Atlanta, GA, 30332-0155. (Telephone: 404-894-6488 or 404-385-2279) (E-mail: larry.frank@arch.gatech.edu)

Research Horizons

Research Notes

Sick Schools

Study finds schools with advanced climate control systems have fewer air pollutants than schools with conventional systems.

Put students in a big closed box with limited fresh air and hope they stay well enough to learn.

photo by T. Michael Keza

That's a crude description of the hazards that a combination of architecture and inadequate ventilation can have on children. The result is an increased exposure to indoor air pollution, which can affect children's health and learning abilities.

Researchers at the Georgia Tech Research Institute (GTRI) have found that schools without advanced climate control systems – which regulate humidity, while bringing in fresh air – have higher levels of airborne pollutants than schools that use such sophisticated systems. The differences are statistically significant, the researchers say.

"Bad air and susceptible kids can lead to sick buildings, ill children and a less effective learning environment," says Charlene Bayer, the GTRI principal research scientist who headed the study.

Her study is one of the few that attempts to statistically quantify exactly what is and isn't floating in the air of school buildings. The study's database of indoor air pollutants found in schools may give scientists new insight into the association between indoor air quality and childhood respiratory problems, such as asthma, she says. This association has been noted in previous research published by the American Society of Heating, Refrigeration, and Air Conditioning Engineers.

GTRI researcher Charlene Bayer led a team of scientists who measured indoor air quality indicators in school classrooms in Georgia. They checked for volatile organic compounds, particles and aerosols, bioaerosols, aldehydes and ketones, carbon dioxide, carbon monoxide, temperature, humidity and air change rate. (300-dpi JPEG version - 220k)

It's a big issue. The U.S. General Accounting Office reports that one in five U.S. schools have indoor air quality problems. And asthma is the top chronic illness of childhood. Of the 26 million Americans who have been diagnosed with asthma, 8.6 million are younger than 18, according to the American Lung Association.

Schools are far more susceptible to air quality problems than most other buildings for several factors, including low budgets, deferred maintenance and high population density, Bayer says. And children – with their developing immune systems – are more significantly affected than adults, she adds.

"We don't know the precise causal link between pollutants and asthma, but we strongly suspect that one is associated with the other," she adds.

To control space humidity, most schools limit the amount of outdoor air that is brought into a building. Conventional packaged cooling units, the kind often used in schools, dehumidify air only when the unit runs to cool the air. The resultant high humidity and reduced ventilation can breed a proliferation of microbes – fungi, mold, mildew and other pollutants.

Newer "desiccant-based outdoor air pre-conditioning systems" can deliver the desired ventilation rates on a continuous basis and control space humidity levels. This is not possible with conventional packaged equipment.

"The desiccant systems may cost more to install than conventional systems, but their increased energy efficiency offers a quick payback in addition to an improved indoor environment," Bayer says.

To find out whether there is a measurable difference in air quality between the two systems, the U.S. Department of Energy funded Bayer's study via a grant to SEMCO Inc., a Missouri-based manufacturer of desiccant systems. The study matched five schools with active humidity control systems with five conventional schools. All are newly constructed and are scattered throughout three cities in different regions of Georgia. None of the schools had previously reported problems with air quality at the time the study began in mid-1998.

Bayer's research team consisted of GTRI scientists, as well as those from the Georgia State University Department of Biology, and John Fischer, a technology consultant for SEMCO.

Four times during a yearlong period, they visited each school to measure numerous air-quality indicators – volatile organic compounds, particles and aerosols, bioaerosols, aldehydes and ketones, carbon dioxide, carbon monoxide, temperature, humidity and air change rate. The researchers' equipment also continuously monitored one room in each school for carbon dioxide, temperature and humidity.

They found that schools with conventional systems had humidity levels above the 50 percent norm that desiccant-based systems provide. Most reached "the breakpoint of 70 percent humidity, above which you have a high probability of microbiological contamination," Bayer says.

As a result, researchers found fungi levels were generally higher in schools without active humidity control. Researchers were surprised that all schools – even the ones with the desiccant-based systems – tested above the national guideline level of 1,000 parts per million (ppm) of carbon dioxide in the air, at some point during the study.

Carbon dioxide levels indicate whether there is sufficient ventilation to remove generated pollutants. When the carbon dioxide level rises above 1,000 ppm, other pollutants are not being removed sufficiently, Bayer explains.

The investigation also revealed that as air filters age in conventional systems, the amount of outdoor air delivered to a building reduces significantly. Because routine climate control system maintenance is lacking in most schools, researchers suggest that system designers should consider the impact of aging filters. Then designers should select minimum outdoor air quantities based upon filters that need replacement, not new clean filters.

"None of the schools we studied operated their systems correctly all the time," Bayer says. "Facility staff members don't understand them and sometimes turn them off when they should remain on."

Only three of the 10 schools investigated provided outdoor air quantities in accordance with national guidelines set by the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE). This finding emphasizes the risk associated with the proposed reduction by ASHRAE of its current recommended minimum ventilation rates, Fischer says.

There were other sources of air pollution. Chemicals often seeped out from markers and other art supplies, and "plug-in" air fresheners were commonly found in the schools; one room had four of them, Bayer reports. "Teachers love plug-ins, but they are a constant emission source, masking one odor with another. And if you have an odor, you have a contaminant in the air."

Bayer is finishing her analysis and expects to present and publish in the conference proceedings of the ASHRAE Indoor Air Quality 2001 meeting scheduled for November. Researchers plan to submit additional papers on various aspects of the study to peer-reviewed journals.

– Renee Twombly, *freelance writer*

> **For more information,** contact Charlene Bayer, Georgia Tech Research Institute, Atlanta, GA 30332-0820. (Telephone: 404-894-5361) (E-mail: charlene.bayer@gtri.gatech.edu); or John Fischer, SEMCO Inc., 737 Terrell Crossing, Marietta, GA 30067 (Telephone: 770-952-6962) (E-mail: johnfischer@worldnet.att.com)

New Help for Repairing Injured Nerves

Biomaterial developed at Georgia Tech is the basis for new nerve cuff.

A device for repairing damaged or severed peripheral nerves recently received clearance from the U.S. Food and Drug Administration for sales in the United States, and it is expected to hit the market this summer.

photo by Gary Meek

The device, called the SaluMedica™ Nerve Cuff, is made from Salubria ™, a moldable, elastic biomaterial developed at the Georgia Institute of Technology. It is being marketed by SaluMedica LLC, an Atlanta company founded and headed by David Ku, the Georgia Tech professor of mechanical engineering who developed the biomaterial. Ku also holds the Lawrence P. Huang Chair of Engineering Entrepreneurship at Georgia Tech and is a professor of surgery at Emory University.

"A typical patient for the Salubria Nerve Cuff is a 3-year-old who has cut her hand badly in a serious accident," Ku explains. "The nerve cuff lets the surgeon repair the nerve so the girl regains feeling and function in her fingertips so she can write."

The SaluMedica™ Nerve Cuff will help repair damaged or severed peripheral nerves. Made from the biomaterial Salubria developed by Dr. David Ku at Georgia Tech, the device recently received clearance from the U.S. Food and Drug Administration for sales in the United States. (300-dpi JPEG version - 1.12MB)

The cuff – a flexible tube about 2 1/2-inches long and available in 2-, 5- and 10-millimeter inner diameters – provides a protective environment to help peripheral nerves grow back together after an injury. Its range of sizes enables the nerve cuff to fit peripheral nerves from about 1 to 8 millimeters in diameter, allowing its use for peripheral nerve trauma in the finger, arm, leg or face.

Before the introduction of the SaluMedica Nerve Cuff, surgeons used a vein or nerve from another part of the patient's body to help bridge the repair. "Our device offers surgeons the ability to repair nerves without a second surgery," says Xavier Sarabia, vice president of SaluMedica. "Eliminating the need for this second surgery reduces the associated costs and the likelihood of medical complications, such as infection."

Surgeons perform about 220,000 nerve repairs in the United States each year, comprising an annual nerve cuff market of an estimated $80 million. SaluMedica is establishing international sales partnerships to market the nerve cuff in Europe and elsewhere.

The nerve cuff is the first Salubria-based product manufactured by SaluMedica, which Ku founded in 1998 with assistance from Georgia Tech's Advanced Technology Development Center. The nerve cuff obtained U.S. market clearance from the FDA through its 510(k) pathway, a method that compares the new product to a previously or currently marketed product. Unlike predicate silicone nerve cuffs that are no longer used in the United States, the SaluMedica Nerve Cuff is made from Salubria, a hydrogel that contains water in similar proportions to human tissue. It is stronger than typical hydrogels used for contact lenses and can withstand millions of load cycles.

Its strength as well as its ability to be molded into anatomical shapes and sterilized makes Salubria a good candidate for medical devices that replace soft tissue in the body, Sarabia says.

"We are excited about the potential applications of Salubria," he adds. "In the near future, we hope to offer patients suffering from knee arthritis a less invasive, more cost-effective alternative to total knee replacement."

The market for applications of Salubria in treatment of knee arthritis is estimated conservatively at $2 billion a year. Other applications for the biomaterial include wound dressings, drug delivery and a spinal disc implant.

– ***Jane M. Sanders***

> **For more information,** contact David Ku, School of Mechanical Engineering, Georgia Institute of Technology, Atlanta, GA 30332-0405. (Telephone: 404-894-6827) (E-mail: david.ku@me.gatech.edu); or Xavier Sarabia, SaluMedica 112 Krog St., Suite 4, Atlanta, GA 30307. (Telephone: 404-589-1727) (E-mail: Xavier.sarabia@salumedica.com)

Marketing NASA Technologies

Georgia Tech opens regional NASA center for technology transfer.

The Georgia Institute of Technology has won a five-year, multimillion-dollar contract to run NASA's Southeastern Regional Technology Transfer Center (SERTTC).

One of six such centers nationwide and housed in Tech's Economic Development Institute (EDI), SERTTC serves Georgia and eight neighboring states. In each, SERTTC has an affiliate organization to identify and contact local industries with potential to use technologies developed by the space agency.

photo courtesy NASA

Advanced sensors, inspection systems, new composite materials and alloys, unique motors and specialized software are among the technologies essential to NASA's space and earth sciences missions. But beyond NASA's highly specialized uses, these innovations often have broader commercial application.

The goal is to get marketable NASA technologies licensed to private firms and demonstrate a public good from NASA research. "We want to brand NASA as a product resource," says EDI's David Bridges, who manages

SERTTC.

SERTTC is seeking industries that can use measuring and detection instruments, gaskets and fasteners, remote sensors and advanced materials, Bridges says. Others include companies that make communications devices, software and energy-related products. Among widely used items stemming from space research are radiation-blocking sunglasses, microcomputers, weather forecasting gear, water purification systems, ultrasound scanners, heart monitors, dry-film machinery lubricants and high-density batteries.

The center can benefit companies in several ways, Bridges explains, by: (1) augmenting product development activities, (2) offering a resource for new product development, (3) reducing time from innovation to market and (4) providing grant money to small firms with promising innovations.

For SERTTC, the process entails NASA field centers in Florida, Alabama and Mississippi sending viable technologies and recommendations to SERTTC for industry matching and outreach.

In Georgia, John Mills, head of Tech's Columbus regional office, will assist SERTTC by contacting manufacturers and serving as the program's technology expert.

"Having SERTTC here will further raise the university's profile in the tech transfer community and enable Georgia Tech to provide additional services to state and regional industry," Bridges says.

– ***Lincoln Bates***

> **For more information,** contact David Bridges, Economic Development Institute, Georgia Institute of Technology, Atlanta, GA 30332-0640. (Telephone: 404-894-6786) (E-mail: david.bridges@edi.gatech.edu)

A Flash of Force

RADAR Flashlight could help police detect suspects hiding behind doors and 8-inch thick walls.

Police officers serving a warrant or searching for a suspect hiding inside a building could soon have a new tool for protecting themselves and finding the "bad guy."

A prototype device called the

RADAR Flashlight, developed at the Georgia Tech Research Institute (GTRI), can detect a human's presence through doors and walls up to 8 inches thick. The device uses a narrow 16-degree radar beam and specialized signal processor to discern respiration and/or movement up to three meters behind a wall. The device can penetrate even heavy clothing to detect respiration and movements of as little as a few millimeters.

photo by Gary Meek

The RADAR Flashlight can detect a human's presence behind doors and walls up to 8 inches thick, says GTRI researcher Gene Greneker, who designed the device.

"We believe the RADAR Flashlight potentially will be useful to police officers in ambush situations," says Gene Greneker, the GTRI principal research scientist who led the development of the device. ".... It is a force multiplier and a safety enhancement tool."

The RADAR Flashlight is undergoing further modification and testing for the next six months. The Georgia Institute of Technology has filed a provisional patent for the device, which could become commercially available to law enforcement officials within a couple of years if the university licenses the technology to a manufacturer.

With funding in 1998 from the National Institute of Justice (NIJ), a division of the U.S. Justice Department, Greneker and his team took the RADAR Flashlight from a bulky three-part prototype to a self-contained unit that weighs about 7 pounds. The NIJ tested the device last year at the National Law Enforcement Corrections Technology Center in Charleston, S.C., and suggested further modifications. Work on those changes is expected to begin this spring with additional funding from the NIJ.

"We will be modifying the RADAR Flashlight based on what law enforcement officials told us from the tests," Greneker says. "For one thing, they said it makes too much noise when it locks onto a wall (to scan). Also, for use by SWAT teams, the RADAR Flashlight needs to be operated by remote control. So we plan to put the RADAR Flashlight on a tripod at least 25 feet away from a wall and steer it by remote control to the part of the wall we're interested in scanning."

When these modifications are complete, the RADAR Flashlight will undergo more rigorous testing in various environmental conditions.

In its current form, the RADAR Flashlight operates in the following manner: The user holds the device with a pistol-grip handle, pulls a trigger, and the device runs a 3-second self-test to verify that it is properly functioning. The user sees the results as a bar graph on a small LED display built into the device. Then the user presses the device against a wall, pulls the trigger and within 3 seconds the system automatically spaces itself from the wall at a distance designed for best performance. The RADAR Flashlight's narrow radar beam sends out a pulse of electromagnetic energy, then detects the return signal, which is read by high-speed signal processing technology that quickly delivers bar-graph results to the user's display. As the person on the other side of the wall breathes, the bar-graph display rises and falls with a rhythmic response.

Research that evolved into the RADAR Flashlight began at GTRI in the mid-1980s with the patenting of a frequency-modulated radar for remotely checking vital signs of soldiers wounded on the battlefield before risking medics' lives to save the injured. This early technology also was tested for its ability to monitor vital signs of soldiers clothed in chemical or biological warfare suits, without requiring them to risk contamination by removing the protective gear.

Today, a technical challenge remains for researchers working on the RADAR Flashlight.

"We have one problem," Greneker says. "This instrument is so sensitive to motion that if you don't hold it still enough, it will detect its own self-motion. If we can overcome this, it would be the Holy Grail, and interestingly enough, we think we know how to solve this problem with additional research."

Bill Deck of the National Law Enforcement Corrections Technology Center says the RADAR Flashlight has potential, but adds that the device's stability and LED display are key issues to target before it is commercialized.

Greneker predicts the cost of the RADAR Flashlight to be between $1,000 and $1,500 to make it affordable to police departments.

– ***Jane M. Sanders***

The full-text version of this article is posted at gtresearchnews.gatech.edu/newsrelease/RADARFLASH.html. **For more information,** you may contact
Gene Greneker, Georgia Tech Research Institute, Atlanta, GA 30332-0856. (Telephone: 770-528-7744) (E-mail: gene.greneker@gtri.gatech.edu).

Also see *Research Links* news stories.

Research Horizons

Research Links...

The Mathematics of Cancer Treatment

Advanced programming techniques offer new weapon against prostate cancer.

A merger of advanced mathematical techniques with cutting-edge computer technology may give doctors a powerful new weapon in the battle against prostate cancer.

Researchers have developed a computerized expert system that would help radiation oncologists optimize placement of radioactive "seeds" for prostate brachytherapy, a non-surgical treatment that has been growing in popularity. Beyond providing treatment more precisely tailored to each patient, the system targets escalated doses of radiation at tumor pockets, and accounts for changes that occur in the prostate volume during treatment. Use of the system has the potential to improve tumor control and reduce uncomfortable side effects.

photo by Gary Meek

Researcher Eva Lee explains how a computerized expert system helps plan the placement of radioactive seeds for prostate cancer treatment. Shown are an ultrasound image of a prostate, a section of the optimization algorithm and a medical illustration of the prostate.

For the cost-conscious medical industry, the automated system offers a dramatic reduction in the time required to design radioactive seed treatment, allowing optimized plans to be created in minutes – and revised as the procedure proceeds.

"The system allows us to effectively manipulate the large number of variables involved, something that is far too complex for even the best human experts," says Eva K. Lee, an assistant professor of industrial and systems engineering at the Georgia Institute of Technology and of radiation oncology at Emory University School of Medicine. "We can deliver better precision and create the optimal plan for each patient. This system should help cut the recurrence rate for prostate cancer and reduce toxicity to healthy tissue."

Prostate brachytherapy involves implantation of tiny radioactive seeds in the cancerous prostate. Continuous radiation from the seeds kills the cancer cells, allowing patients to avoid surgery that can produce such complications as incontinence and impotence.

To successfully treat the cancer, however, physicians must carefully design the radiation dose, balancing the high radiation levels needed to eradicate the cancer against the need to protect nearby tissue, including the urethra and rectum. Further complicating treatment is the edema that occurs as needles are inserted to place the seeds. Resulting changes in prostate volume can mean delivering too little radiation at the beginning of treatment and too much as the swelling subsides.

"It is very complicated to produce a successful implant," explains Lee, who collaborated on the work with Macro Zaider, professor and head of brachytherapy physics at Memorial Sloan Kettering Cancer Center. "Proper coverage of the entire prostate is very important, but it can be very difficult to carry out the plan. The seeds cannot always be placed in the location you want, so you must be able to compensate for that. Our system allows real-time planning, and corrections can be made as you proceed."

Ultrasound images of the patient's prostate are used by the system to help determine optimal radioactive seed placement based on such variables as prostate volume, location of tumor pockets, radioactivity levels of the seeds, location of the urethra (which passes through the prostate) and regions of the organ that may be unreachable by placement needles. Mixed integer programming and computational optimization techniques are the core technological tools utilized.

Woven into the system are a dose-calculation engine, a modeling module, an optimization engine and a graphical evaluation tool. Features include (1) real-time automatic design of seed configuration for use in the operating room, (2) incorporation of magnetic resonance spectroscopy imaging information to target escalated doses to tumor regions, (3) planning that accounts for changes in prostate volume, and (4) an ability to correct seed configuration intra-operatively to account for seed displacement, needle distortion, or unforeseen difficulties encountered during implantation.

"To the physician, this will be a black box," Lee explains. "They will not need to know what is going on with the mathematics. All they will have to do is tell the system what they want in the plan."

Less experienced oncologists working in remote areas could use the system to aid in producing high-quality treatment plans.

In most current treatments, seed placement is determined manually based on a simulation of the patient's prostate. Done days or weeks ahead of the operation, this "pre-plan" takes hours to produce. By cutting the planning time to as little as 15 minutes, the system should reduce costs and allow physicians to spend more time with their patients, Lee notes.

Though the expert system is ready for commercialization, it will have to receive FDA approval before being made available to treatment centers. However, Lee has used real patient data to compare her system against treatment plans designed by radiation oncologists. Those results suggest the system will provide significant improvements in treatment outcomes.

The system operates on a wide range of computing platforms, including Windows NT personal computers.

The work is sponsored by the National Science Foundation and the Whitaker Foundation.

– John Toon

The full-text news release version of this article is posted at gtresearchnews.gatech.edu/newsrelease/lee/lee_news.html. **For more information,** you may contact Eva Lee, School of Industrial and Systems Engineering, Georgia Tech, Atlanta, GA 30332-0205. (Telephone: 404-894-4962) (E-mail: eva.lee@isye.gatech.edu).

Replacing Brawn with Brains

Advanced software algorithms make automation more affordable.

Advanced software algorithms developed at the Georgia Institute of Technology are the foundation for a new robotic motion control system that will help manufacturers reduce the labor involved in routine inspection and material handling tasks.

Produced by Atlanta-based CAMotion Inc., the PC-based software provides greater intelligence for automated operations, allowing off-the-shelf, low-cost robotic equipment to handle tasks previously requiring more precise and much heavier components. CAMotion, whose name is derived from "computer assisted motion," is a member company of the Advanced Technology Development Center (ATDC) at Georgia Tech.

photo by Randal Crow

Johnny Dempsey, left, plant manager, and David Boyd, president of Vulcan Group Inc., examine a part prior to loading into the CAMotion robot for inspection. The Birmingham company uses CAMotion systems to inspect automobile roof racks and to load the racks into shipping containers. (300-dpi JPEG version - 499k)

Though initially targeting manufacturers, the motion control systems could ultimately be used in the service industry, where menial tasks and low wages also make it difficult to maintain a competent staff. Traditional robotic systems have already brought about significant productivity gains in manufacturing processes that involve highly repetitive, difficult and dangerous tasks. CAMotion, however, is taking aim at processes that are now often not cost-effective to automate: assembly operations, loading and unloading containers or machines, and inspecting products for quality standards.

"Our goal is to help companies apply automation to routine and menial tasks, the very things that companies have trouble finding people to do these days, and the things that often keep U.S. manufacturers from being competitive," says Steve Dickerson, a professor emeritus of mechanical engineering and chairman of the company. "If you look at what people do in factories and in the service sector, direct labor is now almost entirely used for motion.

"The fact that people have good hand-eye coordination and the intelligence to know the next task means that people in manufacturing are used almost exclusively for moving things around," he explains. "These tasks do not require the same precision as placing components onto a circuit board, but the large-scale motions across three dimensions have made them difficult to automate in a cost-effective way."

CAMotion's first customer is Vulcan Group in Birmingham, Ala. The company uses two CAMotion systems, one to inspect automobile roof racks after painting, and the other to stack the completed parts in a shipping container. As part of the inspection task, a gantry-type robot moves both the parts and the vision system to acquire 24 different images of each part to evaluate them for paint quality.

"CAMotion created a solution for us when no one else could" says David Boyd, president of Vulcan Group. "We are very pleased with the system; in fact, we believe that it will revolutionize the way painted parts are inspected in the automotive industry."

Three types of algorithms, all developed by researchers in Georgia Tech's Manufacturing Research Center, are included in CAMotion's software:

- A vibration control algorithm plans the robotic axis trajectory in such a way as to avoid creating unnecessary oscillation. By "damping out" the vibration, the "intelligent trajectory" allows the use of lighter and less expensive components.

- A learning algorithm helps the equipment to improve its own performance based on feedforward. This typically produces a 10-to-1 reduction in dynamic error.

- Position estimation software, combining machine vision, encoders and accelerometers, helps the system know its own location relative to the work and thus how to move to accomplish a task.

"We can build a machine that is not as rigid and precise because our software compensates for that," says Bob Purcell, the company's president. "Therefore, we can build automation equipment with the same level or a higher level of performance at less expense. What differentiates us is the ability to produce a machine that is very cost effective for a variety of tasks."

By using standard components and smart software control, Purcell hopes to make automating those tasks competitive given the rising cost and scarcity of direct labor. Beyond the use of standard robotic components, CAMotion will use a single software package for all of its applications.

Changes to numerical tables in the software allow it to handle a wide range of different tasks, providing a degree of flexibility that has been lacking in automated systems. The software behind CAMotion was developed with support from the National Center for Manufacturing Sciences, a consortium of manufacturers. Faculty members working on that project, including Wayne Book, Nader Sadegh and Dickerson, saw the business potential for the techniques and obtained a $50,000 Faculty Research Commercialization Program grant from the ATDC to move their research toward commercialization.

– John Toon

The full-text news release version of this article is posted at gtresearchnews.

gatech.edu/newsrelease/CAMOTION.html. **For more information,** you may contact Bob Purcell, CAMotion Inc., 430 10th St., Atlanta, GA 30318. (Telephone: 404-874-0090) (E-mail: bob.purcell@mindspring.com).

Faculty Awards and Honors

Georgia Tech faculty and staff receive recognition.

Barbara Blackbourn-Jansma of the School of Modern Languages was nominated as International Poet of the Year. She has also been named International Poet of Merit and was invited to compete at the International Society of Poets Spring Convention and Symposium in early March for International Poet of the Year 2001.

Jeffrey A. Davis of the School of Electrical and Computer Engineering received a National Science Foundation CAREER Award for "Interconnect Dominant Ultra Large-Scale Integrated Design: A New Paradigm for 21st Century Integrated Circuit Design and Education."

Imme Ebert-Uphoff of the School of Mechanical Engineering won the 2001 Robert W. Galvin Outstanding Young Manufacturing Engineer Award from the Society of Manufacturing Engineers.

Mostafa El-Sayed of the School of Chemistry and Biochemistry was elected a fellow of the American Physical Society. This is in addition to his election this year as a fellow of the American Association for the Advancement of Science.

Nicholas V. Hud of the School of Chemistry and Biochemistry received a Research Innovation Award from Research Corporation to support his research into the development of novel methods for controlling DNA condensation.

Gary B. Schuster, dean of the College of Sciences, was elected chairman of the American Association for the Advancement of Science Section on Chemistry.

C. David Sherrill of the School of Chemistry and Biochemistry received the *International Journal of Quantum Chemistry* Young Investigator's Award.

Charles Ume of the School of Mechanical Engineering was named the co-editor-in-chief of *Mechatronics: An International Journal*.

Kurt Wiesenfeld of the School of Physics was elected a fellow of the American Physical Society. The citation reads: "For seminal theoretical contributions to nonlinear dynamics and complex systems theory, including co-discovery of self-organized criticality and for theories of stochastic resonance and Josephson-junction phase locking."

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