

SPOTLIGHT NOTES

The Power of One

Unicellular organisms contribute nitrogen.

Large, nutrient-poor expanses of the open ocean are getting a substantial nitrogen influx from an abundant group of unicellular organisms that “fix,” or chemically alter, nitrogen into a form usable for biological productivity.

First identified about five years ago, these organisms — about 7 microns in diameter — are fixing nitrogen at rates up to three times higher than previously reported for the Pacific Ocean, according to research published in the Aug. 26, 2004 edition of the journal *Nature*. On a transect from Oahu, Hawaii, to San Diego, Calif., researchers measured some of the highest rates in this study: Seven milligrams of nitrogen — an essential nutrient for the growth of many organisms — were being injected into the phytoplankton and other organic materials in every square meter of the ocean surface.

“To our surprise, these unicellular nitrogen-fixers are broadly distributed spatially and vertically distributed at least down to 100 meters, and they’re fixing nitrogen at quite high rates,” says lead author Joe Montoya, an associate pro-



On one of their research cruises, this one north of Australia, researchers Doug Capone, left, of the University of Southern California, and Joe Montoya, of Georgia Tech, watch the sun rise before a long day of biological sampling at sea.

fessor of biology at Georgia Tech.

“The rates we measured imply a total input of nitrogen that exceeds the nitrogen fixation rate measured for the cyanobacteria *Trichodesmium* (traditionally believed to be the dominant marine nitrogen-fixer) in the Pacific Ocean. These unicells are the largest single source of nitrogen

entering the water in broad areas of the ocean.”

This level of nitrogen fixation in the Pacific Ocean alone accounts for about 10 percent of the total global oceanic new production of biomass, according to the researchers’ preliminary calculations.

“This is globally important because new production in the ocean is a key

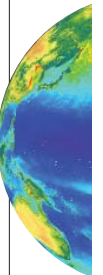
force driving the uptake of carbon dioxide from the atmosphere into the ocean,” Montoya explains. “This represents a route for trapping and sequestering carbon dioxide and keeping it out of atmospheric circulation for some time.”

Carbon dioxide is one of the naturally occurring gases that traps energy from the sun and helps maintain hospitable temperatures on Earth, creating the “greenhouse effect.” But studies indicate that greenhouse gases that form from vehicle and industrial emissions are enhancing the greenhouse effect and contributing to global climate warming.

With funding from the National Science Foundation (NSF), Montoya began this research five years ago with colleague Jonathan Zehr, a professor of molecular biol-



Researchers sample ocean water with a CTD-rosette, which consists of an aluminum frame, a sensor system and 24, 10-liter PVC sampling bottles. The equipment’s sensors transmit real-time information on the physical and chemical structure of the water via a conducting cable.



ogy at the University of California at Santa Cruz, and one of the authors on this *Nature* paper. The other authors are Georgia Tech graduate student Carolyn Holl, University of Hawaii graduate student Andrew Hansen, University of Texas at Austin Associate Professor of Marine Science Tracy Villareal and University of Southern California Professor of Marine Science Douglas Capone.

The research team's findings — resulting from several month-long research cruises — have prompted a follow-up study recently funded by NSF. The scientists will continue to survey the Pacific Ocean, as well as the North Atlantic and the South Pacific oceans in two more research cruises in 2006 and 2007.

— Jane M. Sanders

© Contact: Joe Montoya at 404-385-0479 or joseph.montoya@biology.gatech.edu. Read more at gtresearchnews.gatech.edu/newsrelease/nitrogen.htm.

Above: In this image, the deep blue areas are the nutrient-poor and thus low-fertility, central gyres of the ocean. Fewer phytoplankton grow here. The lighter blue areas represent more productive regions. The upwelling region around the equator has more nutrient input and therefore, higher biomass.

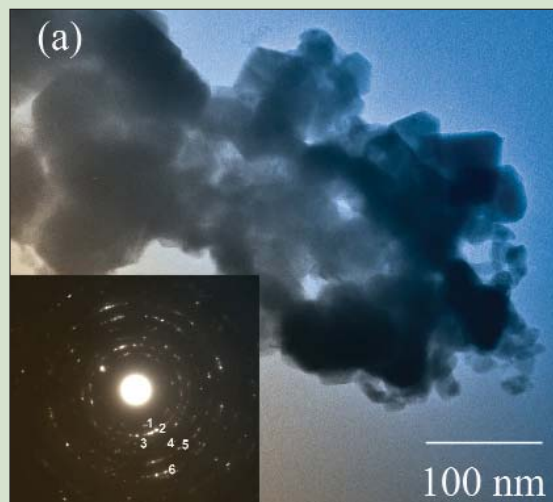
Functionally Graded Electrodes

Taking advantage of an electrochemical phenomenon that had previously been considered a nuisance, researchers at the Georgia Institute of Technology have developed a new class of 3-D nanoporous electrodes that could boost the performance of fuel cells, batteries and sensors.

By generating hydrogen bubbles during the deposition of copper, tin or a copper-tin alloy onto a copper substrate, the researchers create self-supported metallic foam electrodes that contain a complex network of interconnected pores. Because the bubbles expand as they move away from the substrate, they create passageways through the deposited metal that become wider the closer they get to the outside of the electrode.

The tapered passageways should allow gases and fluids to move more easily through these “functionally graded” electrodes, boosting the performance of solid-oxide fuel cells, lithium batteries and chemical sensors. The nanoporous nature of the structures provides a large surface area on which electrochemical reactions can take place.

“By adjusting the prop-

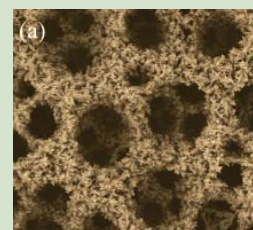


A transmission electron microscope image shows the copper branches of a 3-D foam structure with the corresponding electron diffraction patterns (inset). Color has been added to this image.

erties of the electrolyte — the viscosity and chemical composition — we can change the size of the gas bubbles we generate,” explains Meilin Liu, a professor in Georgia Tech's School of Materials Science and Engineering. “Getting the bubbles small enough allows us to produce three-dimensional nanostructures in which the pores are small on the inside but taper to larger pores on the outside.”

The research, supported by the Office of Basic Energy Sciences in the U.S. Department of Energy, was reported in the journal *Advanced Materials*.

The process developed by Liu and Heon-Cheol Shin and Jian Dong offers a simpler means of producing electrodes that facilitate the movement of liquids and



This image shows 3-D foam structures of copper deposits formed by an electrodeposition process for 20 seconds. Color has been added to this image.

gases.

“In our electrode, the gradient is created naturally and is ideal for our needs,” explains Liu, co-director of Georgia Tech's Center for Innovative Fuel Cell and Battery Technologies. “That is really the utility of this process. You can avoid the complexity of creating multiple layers.”

— John Toon

© Contact: Meilin Liu at 404-894-6114 or meilin.liu@mse.gatech.edu. Read more at gtresearchnews.gatech.edu/newsrelease/nanoporous.htm.

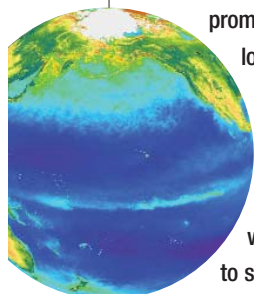


IMAGE COURTESY NOAA

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PHOTO BY LANDE CPL. K.T. TRAN, COURTESY USMC

Cpl. Jason R. Slemmer works in a Camp Pendleton warehouse lit by energy-efficient T-5 high-output fluorescent lamps.

Gung Ho for Saving Energy

An energy conservation analysis by a team of Georgia Tech researchers is expected to save the U.S. Marine Corps about \$1.85 million annually at seven bases in California and Arizona.

Researchers recommended 75 energy conservation opportunities that will allow the Marines to recover an estimated \$4.9 million investment in about 2.7 years, says Bob Martin, a Georgia Tech Research Institute (GTRI) engineer who led the 12-member team of GTRI and Economic Development Institute (EDI) researchers in the project in 2003. The effort was part of the Western Power Grid Peak Demand and Energy Reduction Program led by prime contractor Intuitive Research & Technology Corporation of Huntsville,

Ala. This project also included researchers from Texas A&M University, and the U.S. Department of Energy's Pacific Northwest and Lawrence Livermore national laboratories.

"California's recent power crisis provided the impetus for this project, but it was one of many programs aimed at cutting energy costs," says Bill Meffert, manager of energy and environmental management services at EDI.

Some facilities, including Twenty-Nine Palms and Camp Pendleton, resemble commercial facilities with an emphasis on conserving energy such as that used for lighting and air conditioning.

"The easy projects had already been done," Martin says. "We had to dig into systems performance to find opportunities."

Other places, such as the Logistics Center at Barstow, worked more like

an industrial plant. "This is where we shine," says Meffert, noting that the team found more than \$833,000 in annual savings, or some 20 percent of the base's yearly energy expenditures.

Audits, surveys and data logging resulted in recommendations as simple as decommissioning old paint booths and as complex as recovering heat from the exhaust of a thermal regenerative oxidizer. "We found that industrial systems haven't gotten nearly the attention that building systems have," Meffert adds.

With this work complete, Georgia Tech hopes to apply the lessons learned to Georgia's Warner Robins Air Logistics Center and the Albany Marine Corps Logistics Base — with their heavy maintenance activities.

— Lincoln Bates

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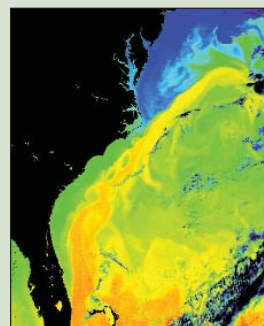


IMAGE COURTESY NASA

In this false-color image, the warm Gulf Stream current can be seen flowing to the northeast off of the United States' eastern seaboard in April 2003.

Abrupt Climate Change

Research published in June in the journal *Science* supports the hypothesis that heat transfer by ocean currents — rather than global heating or cooling — may have caused the global temperature patterns associated with abrupt climate changes in the North Atlantic in the past 80,000 years.

Authored by the University of Bremen's Frank Lamy and colleagues, the article provides new evidence that Southern Hemisphere climate may not have changed in step with Northern Hemisphere climate. Though these new measurements of ocean surface temperature off Chile are consistent with information from Antarctic ice core samples, they still contradict measurements made on land in the Southern Hemisphere — suggesting more research is needed to resolve the issue.

Scientists have found evidence of rapid and dramatic climate change that occurred in just decades during cool periods of the past 80,000 years in the North Atlantic. Knowing whether climate changes took place simultaneously in the Northern and Southern hemispheres is vital to understanding the mechanism involved — and

assessing whether similar abrupt climate change could be a threat today.

“People are very interested in these dramatic climate changes because they occur on very human time scales,” says Jean Lynch-Stieglitz, an associate professor in Georgia Tech’s School of Earth and Atmospheric Sciences and author of a “Perspectives” article that accompanied the Lamy paper in *Science*. “It’s really important to understand what is causing them and what conditions are necessary for the climate to rapidly transition from cold to warm and back again.”

The Northern Hemisphere has been well studied, but comparatively little data exists on the Southern Hemisphere, which has more open ocean

area. And the information that exists about the Southern Hemisphere is contradictory.

— John Toon

© Contact: Jean Lynch-Stieglitz at 404-894-3944 or jean@eas.gatech.edu. Read more at: gtresearchnews.gatech.edu/newsrelease/abruptchange.htm.

Closing the Loop

In electronics assembly, 60 to 70 percent of final defects occur during the stencil printing process (SPP), a stage of surface-mount technology for printed circuit board assembly.

To address this problem, engineers at Georgia Tech’s Center for Board Assembly Research (CBAR) have developed a new data-driven, closed-loop control technology that adjusts equipment parameters in real time, resulting in fewer defects and higher yields.

In SPP, a metallic stencil is placed over the printed circuit board, and a squeegee pushes solder paste through apertures in the stencil onto the board’s surface where components are placed for electrical connections. The goal is to deposit the solder on the pad as accurately as possible because unevenly applied paste can cause defects.

Solder deposition is affected by variations in air temperature, chemical-physical characteristics of the solder paste and aging stencils. The shrinking of components and an increase in circuit density present even bigger challenges.

“That reduces the distance between components’ leads, which makes the deposition of solder paste even more difficult,” says Alex Goldstein, director of operations at CBAR, part of

Tech’s Manufacturing Research Center.

Screen-printer operators gauge product quality by sight. Sometimes, automated optical inspection (AOI) technology can assess quality, but humans still must decide how to adjust machine settings based on data presented by the AOI.

CBAR’s innovative technology closes the loop between AOI systems and stencil printers, automatically assessing quality and adjusting machine parameters in real time.

In April, Speedline Technologies licensed the technology. CBAR will work with Speedline to enhance the technology.

— T.J. Becker

© Contact Alex Goldstein at 404-894-9355 or alex.goldstein@marc.gatech.edu. Read more at: gtresearchnews.gatech.edu/newsrelease/speedline.htm



Engineers at Georgia Tech’s Center for Board Assembly Research (CBAR) have developed technology to reduce defects and increase yields in electronic assembly. CBAR director of operations Alex Goldstein, left, and Assistant Professor Magnus Egerstedt were among those working on the project.

SEMICONDUCTOR

Microcantilever heaters fabricated by William King's research team are made of crystalline silicon and have been engineered with atomic impurities that allow electricity to flow through them.

Georgia Tech researchers William King, standing, Brent Nelson, left, and Tanya Wright use AFM-generated images to analyze nanometer-scale structures.

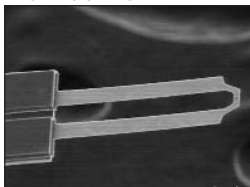
Tiny Writing

Researchers develop improved method to produce nanometer-scale patterns.

Researchers from the Georgia Institute of Technology and the Naval Research Laboratory (NRL) have developed an improved method to directly write nanometer-scale patterns onto a variety of surfaces.

The new writing method, dubbed "thermal dip pen nanolithography," represents an important extension for dip pen nanolithography (DPN), an increasingly popular technique that uses atomic force microscopy (AFM) probes as pens to produce nanometer-scale patterns.

IMAGE BY J. CHAREST



In conventional DPN, a probe tip is coated with a liquid ink, which then flows onto the surface to make patterns wherever the tip makes contact. Dozens of research groups worldwide are working on DPN applications, but the technique — which uses the AFM tips to both sense surface patterns and write new patterns — has been limited by an inability to turn the ink flow on and off. Existing dip pens apply ink as long as they remain in contact with a surface.

The thermal DPN (tDPN) method described by the Georgia Tech and NRL scientists solves that problem by using easily-melted solid inks and special AFM probes with built-in heaters that allow writing to be turned on and off at will. The tDPN technique could be used to produce features too small to be formed with light-based lithography, and as a nanoscale soldering iron for repairing circuitry on semiconductor chips. The technique could also provide a new tool

for studying basic nanotechnology phenomena.

"This technique extends DPN into new sets of materials and provides a higher degree of control," says Lloyd J. Whitman, head of the Surface Nanoscience and Sensor Technology Section at NRL in Washington, D.C. "We also believe this technique will extend DPN into new environments, such as the vacuum environments that would be more compatible with conventional semiconductor device fabrication."

The tDPN technique is described in the Aug. 30, 2004 issue of the journal *Applied Physics Letters*. The research was sponsored by the National Science Foundation, Office of Naval Research and Air Force Office of Scientific Research.

"We've created a heated AFM tip that gives us control over the deposition and deposition rate during writing," says William King, an assistant professor in Georgia Tech's School of Mechanical Engineering.

"We can turn the cantilever heating on and off, so for the first time we can write in some places and not in others."

Combining thousands of individually-controlled AFM pens into arrays could allow writing of complex semiconductor patterns. King says the thermal dip pen technique could produce features as small as 10 nanometers, well beyond the limits of conventional semiconductor patterning processes that depend on light projected through a lithographic mask.

— John Toon

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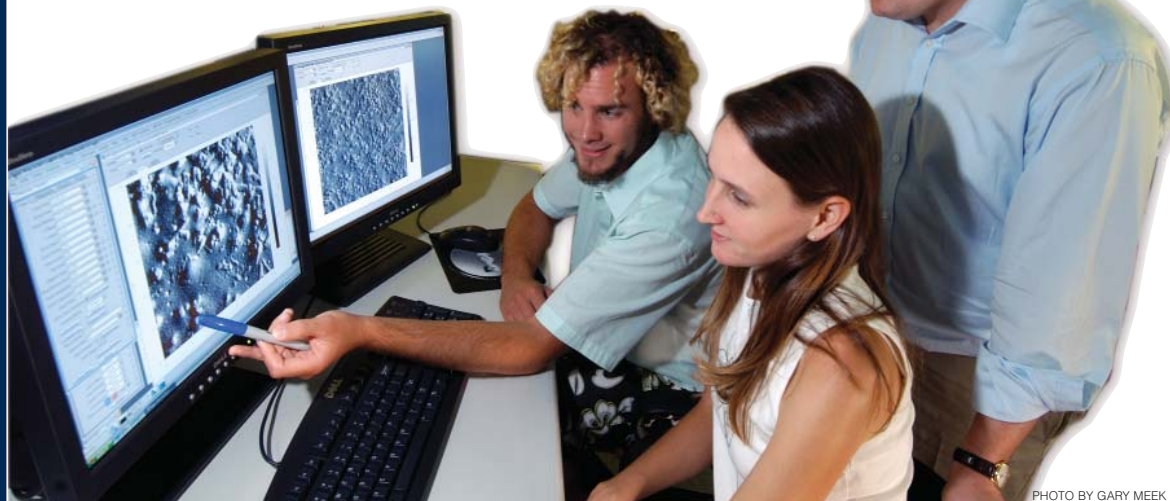


PHOTO BY GARY MEEK

Gold Quantum Dots

A new class of water-soluble quantum dots made from small numbers of gold atoms could be the basis for a new biological labeling system with narrower excitation spectra, smaller particle size and fluorescence comparable to systems based on semiconductor quantum dots.

Providing the “missing link” between atomic and nanoparticle behavior in noble metals, these multi-electron “artificial atoms” could also serve as light-emitting sources in nanoscale optoelectronics and in energy transfer pairs.

“We have discovered a new class of quantum dots that are water soluble, strongly fluorescent, and display discrete excitation and emission spectra that make them poten-

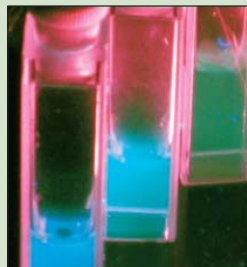


IMAGE COURTESY ROBERT DICKSON

tially very useful for biological labeling,” says Robert Dickson, an associate professor in the School of Chemistry and Biochemistry at the Georgia Institute of Technology. “Their potential applications are really complementary to those of semiconductor quantum dots.”

The gold nanodots are made up of 5, 8, 13, 23 or 31 atoms, each size fluorescing at

a different wavelength to produce ultraviolet, blue, green, red and infrared emissions, respectively. The fluorescence energy varies according to the radius of the quantum dot, with the smallest structures the most efficient at light emission.

In contrast, quantum dots made from semiconductors such as cadmium selenide are much larger, containing hundreds or thousands of atoms. Semiconductor quantum dots obey different size scaling under confinement, producing weaker emissions.

The gold quantum dots were reported Aug. 13, 2004 in the journal *Physical Review Letters* and highlighted on the journal cover. The work was sponsored by the National Science Foundation, National Institutes of Health, Sloan and Dreyfus Foundations, Blanchard and Vassar Woolley Endowments and the Georgia Tech Center for Advanced Research in Optical Microscopy.

In addition to Dickson, the research team includes Professor Yih Ling Tzeng of Emory University; Jie Zheng, Lynn Capadona and Caiwei Zhang of Georgia Tech, and Jeffrey Petty of Furman University.

Because of their narrow excitation spectra and small physical size, the gold quantum dots could be particularly useful in fluorescence resonance energy transfer (FRET) systems, in which emission

from one nanodot would be used to excite another as a means of measuring proximity.

— John Toon

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Heating Up

Rapid urbanization in southeastern China in the past 25 years is responsible for an estimated warming rate much larger than previous estimates for other periods and locations, according to a new study funded by NASA.

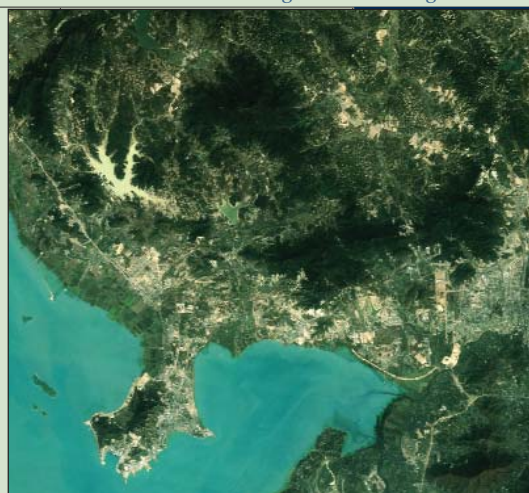
Researchers led by the Georgia Institute of Technology report that the mean surface temperature in the region has risen 0.09 degrees Fahrenheit (0.05 degrees Celsius) per decade since 1979. Also, nighttime low temperatures have risen much faster than the daytime high temperatures. The average reduction of the day-to-night temperature range was 0.24 degrees F (0.132 degrees C) per decade. Their findings appeared in the June 29, 2004 print edition of the journal *Proceedings of the National Academy of Sciences*.

To estimate the temperature changes due to urbanization, researchers used a new approach that integrated meteorological station observations, model-assimilated temperature predictions, satellite-measured greenness and

China's census data. The modeling data — provided by the National Oceanic and Atmospheric Administration's Centers for Environmental Prediction and the U.S. Department of Energy — is considered more accurate than previous information because of its improvements in accounting for temperature range differences affected by cloud cover and soil moisture, the researchers note.

“These results are further evidence of the human impact on climate,” says lead author Liming Zhou, a Georgia Tech researcher working with Professor Robert Dickinson, a global climate modeler in the Georgia Tech School of Earth and Atmospheric Sciences.

Carbon dioxide from industrial and automobile emissions is suspected to be the primary force in global warming. Scientists attribute a 0.9 degrees F (0.5 degrees C) increase in global temperature in the 20th century to a significant atmospheric increase of greenhouse gases, including carbon dioxide. They predict



A NASA satellite image shows Shenzhen in southeast China in 1988 before rapid urbanization removed much of the area's vegetation.

Left: Solutions of gold nanoclusters dissolved in water fluoresce. These nanoclusters behave like multi-electron artificial atoms, emitting at discrete wavelengths in the visible and infrared spectrums. The wavelength increases with the size of the cluster.

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Above right: A NASA satellite image taken in 1996 shows the loss of vegetation because of rapid urbanization in Shenzhen in southeast China. A new study shows this rapid urbanization is a significant contributing factor in warming the region's climate.



IMAGE COURTESY NASA

this increase will continue through the 21st century and cause continued increases in extreme weather, rising sea levels, and the retreat of glaciers and polar ice caps.

“Human-induced changes in land use — such as urbanization, deforestation, and agricultural and irrigation practices — can affect local and regional climate and even large-scale atmospheric circulations,” Zhou explains. “They may have changed climate as much as greenhouse gases over some particular regions of land.”

It is not yet possible to establish the extent to which these temperature changes affect climate on a larger scale, Zhou adds. More research must be done to make this determination because it's a challenge to differentiate the impact of land use changes on climate from that of industrial emissions because both tend to warm the earth and decrease the day-to-night temperature range.

— Jane M. Sanders

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Dynamic Ice

A technique borrowed from the surface physics community is helping chemists and atmospheric scientists understand the complex chemical reactions that occur on low-temperature ice.

Known as electron-stimulated desorption (ESD), the technique uses low-energy electrons to locally probe surfaces, differentiating their characteristics from those of the bulk material below them. Using ESD, researchers at the Georgia Institute of Technology have demonstrated that hydrochloric acid (HCl) quickly dissociates upon contact with icy surfaces — even at temperatures well below 100 degrees Kelvin, conditions seen naturally only in the outer solar system.

The work could lead to a better understanding of the complex atmospheric chemistry occurring in stratospheric ice crystals, the polar ice caps, aerosols containing ocean salt — and even the interface between water and DNA, says Janine Herring-Captain, a doctoral student in the School of Chemistry and Biochemistry.

Using an ultra-high vacuum chamber, Herring-Captain used ESD to study HCl interactions with a variety of ice surfaces across a range of temperatures and pressures. This research, believed to be the first electron-energy, phase and temperature-dependent

ESD study of cluster ion formation and HCl dissociation on ice surfaces, was published May 13, 2004 in *Physical Review Letters*.

Sponsored by the U.S. Department of Energy, the work is part of a long-term study of electron collisions with complex targets and reactions on ice of various kinds — a material much more complex than it appears.

“As chemical physicists, we have to look at low temperature ice as a very dynamic

surface. Ice is a stage for chemicals to meet each other and then react,” says Thomas Orlando, co-author of the paper and chair of Georgia Tech's School of Chemistry and Biochemistry. “This ice stage is intimately involved in the reactions, and without it, many reactions probably wouldn't occur.”

— John Toon

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Researchers at the Georgia Institute of Technology have used electron-stimulated desorption to study chemical reactions in icy surfaces. The work could lead to a better understanding of chemical reactions taking place in Antarctica (shown here), as well as in stratospheric ice crystals.

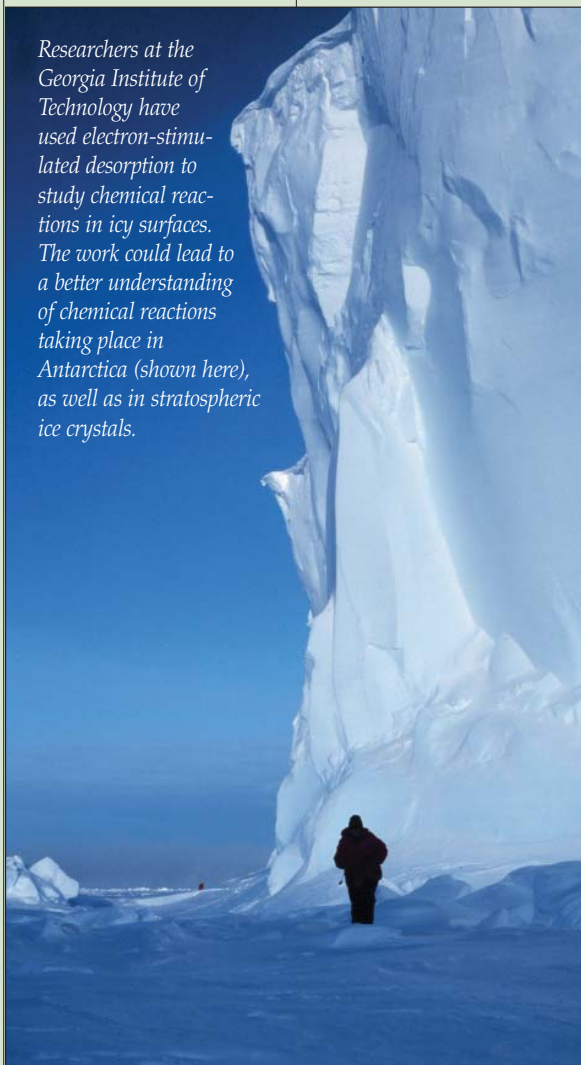


IMAGE COURTESY NOAA

Real-time Testing for PKU

First-ever self-monitoring device is under development for rare genetic disorder.

BY T.J. BECKER

Home-testing kits have made it easier for diabetics and hypertension patients to track their conditions, but such self-monitoring hasn't been possible for people with phenylketonuria (PKU). Georgia Tech researchers and an Atlanta start-up company hope to change that by introducing the first home-testing device for PKU patients.

PKU is a genetic metabolic disorder in which the body lacks a liver enzyme needed to process phenylalanine, an essential amino acid, into another amino acid (tyrosine) used by the body. Left unconverted, excessive amounts of phenylalanine in the bloodstream are toxic to brain tissue and the central nervous system; if untreated in newborns, PKU can cause brain damage and mental retardation.

There is no drug that can cure PKU. It can only be treated through diet. "When phenylalanine levels become too high, PKU patients can suffer movement disorders, such as tremors, seizures and hyperactivity," explains project director Jeff Sitterle, chief scientist at the Georgia Tech Research Institute (GTRI).

Blood-testing requirements vary, but frequent monitoring is very important for children. Frequent testing can be costly and inconvenient for patients who must travel long distances to reach a center.

Because PKU is considered an "orphan disease" — one that affects a small sector of the population — large pharmaceutical companies haven't pursued a home test for the disease.

"Incidence of PKU varies around the world," says Richard Shunnarah, president of Atlanta-based MetGen Inc., which is developing blood-monitoring devices for metabolic genetic disorders. In the United States, PKU occurs in about one in 10,000 births, he adds.

Shunnarah launched MetGen in 2002 and approached Georgia Tech for help in developing a PKU home test. The testing device will store data, providing a history for doctors to review during patients' routine checkups. "That gives doctors a true trend picture, rather than blood levels that might have resulted from patients making a sudden effort to stick to their diet prior to the checkup," Sitterle adds.

The project is a collaboration between GTRI engineers, who built the device's electronics, and Regents Professor of Chemistry and Biochemistry Sheldon May, who developed a special reagent strip for the device. Graduate student Veronica de Silva assisted May.

Like diabetics using blood-glucose home tests, PKU patients prick their fingers and then place a drop of blood on the reagent strip inserted in the testing device. Phenylalanine in the blood prompts a reaction on the test strip. Then the device's electronics calculate how fast the strip absorbs a specific color of light — indicating the level of phenylalanine in the blood.

"That may sound simple, but it actually requires thousands of measurements and a mathematical algo-

rithm to pinpoint the right section of data to evaluate," explains Tim Strike, associate head of the Technology Application Branch in GTRI's Electronic Systems Lab.

As they intended, researchers limited consumer costs by using off-the-shelf components. "Because PKU is an orphan disease, we wanted a device that would be affordable to produce in smaller numbers," says project collaborator Ron Bohlander, director of GTRI's Commercial Product Realization Office.

Another challenge was user-friendliness. "If you have too many steps to follow, it can be confusing for new users — and downright irritating when you use it on a regular basis," Strike adds. "We wanted to make this as easy as buying a soft drink from a machine."

This past summer, scientists at Emory University — where Georgia's only PKU treatment center is located — worked to validate the technology. Since then, Georgia Tech has been helping MetGen find manufacturers for the chemical strip and electronic device. MetGen hopes to win FDA approval by the end of 2004 and begin marketing the PKU home test in early 2005.

Earlier this year, MetGen received an \$85,000 grant from the Georgia Research Alliance's (GRA) Innovation Fund. "Without GRA's assistance, we would have had to seek outside investors, and that would have been difficult due to the size and uniqueness of this market," Shunnarah adds.

© Contact: Jeff Sitterle, GTRI, 404-894-1254 or 404-894-3369 or jeffrey.sitterle@gtri.gatech.edu; or Richard Shunnarah, MetGen Inc., 404-256-1464 or rshunnarah@metgenco.com. Read more at: gtresearchnews.gatech.edu/reshor/rh-f04/pku.html

Researchers Tim Strike, left, and Ron Bohlander are among the Georgia Tech researchers working with Atlanta start-up company MetGen Inc. in the development of the first home-testing device for PKU patients.



PHOTO BY NICOLE CAPPELLO