

Vacuum Evaporator Purchased in 1957 Still Going Strong

A 1957 classic sits in the Georgia Tech Research Institute (GTRI) clean room. It's not a Chevy, but a Veeco vacuum evaporator more than six feet tall and five feet wide.

The evaporator, still in use today, deposits thin films necessary for microfabrication processes. Applications include creating the reflective or anti-reflective coatings on optics and building up layers of insulators, semiconductors and conductors to form integrated electronic circuits.

"It's a very rugged machine and it's gotten better with age," says Mike Harris, a GTRI principal research engineer who first used the Model 775 evaporator in 1972 as a student.

The system operates by evaporating a source material, such as a metal, in a high vacuum, allowing vapor particles to travel directly to a target object, such as a semiconductor, where they condense back to a solid state and form a thin film of the source material.

Harris attributes the machine's longevity to its design and

documentation – and to the skills of GTRI technicians and engineers. "The operator and maintenance manuals are excellent, with exploded views of the various piece parts, making it very easy for our technicians and engineers to repair it when we have problems," he explains.

In addition to repairing the system, GTRI engineers have upgraded and modified the evaporator several times since it was purchased.

First, they changed the high vacuum pump from a diffusion pump to a more modern cryogenic pump in 2002. The diffusion pump generated a high speed jet of vapor by boiling fluid and directing the vapor in the pump throat down into the bottom of the pump and out the exhaust. The newer cryogenic pump traps gases and vapors by condensing them on a cold surface.

To increase the uniformity of results, GTRI researchers added a planetary substrate fixture that rotates inside the evaporation chamber.



Carefully maintained and updated, a 50-year-old vacuum evaporator is still applying coatings in a Georgia Tech Research Institute clean room.

In addition, the original system was designed with a tungsten filament that was heated to a high enough temperature so that the source material placed in a crucible on the filament evaporated. GTRI engineers changed this to an electron beam evaporator that fires a high-energy beam from an electron gun to boil a small spot of material, allowing lower vapor pressure materials to be deposited.

Since the 1957 system still runs and remains optimal for numerous

applications, Harris sees no reason to buy a new one. "New systems like this probably cost between \$700,000 and \$1 million," he adds. "And the new systems are designed primarily for throughput and that's not necessarily best for a research environment."

– Abby Vogel

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Platinum Nanocrystals Boost Catalytic Activity

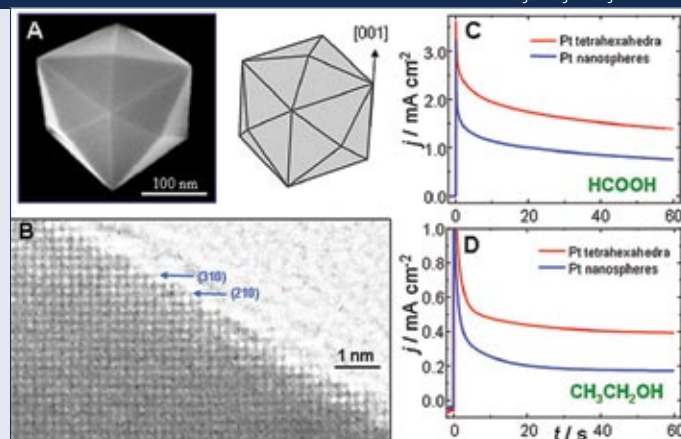
A research team from two continents has produced a new form of the industrially important metal platinum: 24-facet nanocrystals whose catalytic activity per unit area can be as much as four times higher than existing commercial platinum catalysts.

The nanocrystals, whose "tetrahexahedral" structure had not previously been reported in the metal, could improve the efficiency of chemical processes such as those used to catalyze fuel oxidation and produce hydrogen for fuel cells.

"If we are going to have a

hydrogen economy, we will need better catalysts," says Zhong Lin Wang, a Regents' Professor in the Georgia Tech School of Materials Science and Engineering. "This new shape for platinum catalyst nanoparticles greatly improves their activity. This work also demonstrates a new method for producing metallic nanocrystals with high-energy surfaces."

The new nanocrystals, produced electrochemically from platinum nanospheres on a carbon substrate, remain stable at high temperatures. Their sizes can be



(A) Low-magnification image shows a platinum tetrahexahedral (THH) nanocrystal and its geometrical model, while (B) a high-resolution image reveals surface atomic steps in the areas made of two different sub-facets.

controlled by varying the number of cycles of “square wave” electrical potential applied to them.

“This electrochemical technique is vital to producing such tetrahedral platinum nanocrystals,” explains Shi-Gang Sun, an Eminent Professor in the College of Chemistry and Chemical Engineering at the Xiamen University in China. “The technique used to produce the new platinum nanostructures may also have applications to other catalytic metals.”

The research was supported by the Natural Science Foundation of China, Special Funds for Major State Basic Research Project of China and the U.S. National Science Foundation. Details were reported in May 2007 in the journal *Science*.

Platinum serves as a catalyst in industrial chemical processing, motor

vehicle catalytic converters, fuel cells and sensors. Commercially available platinum nanocrystals – which exist as cubes, tetrahedra and octahedra – have what are termed “low-index” facets. Because of their higher catalytic activity, “high-index” surfaces would be preferable – but until now, platinum nanocrystals with such surfaces had never been synthesized.

The nanocrystals produced by the U.S.-Chinese team have high energy surfaces that include numerous “dangling bonds” and “atomic steps” that facilitate chemical reactions. These structures remain stable at high temperatures – up to 800 degrees Celsius in testing done so far. That stability will allow them to be recycled and re-used in catalytic reactions, Wang said.

Though the process must still be fine-tuned, the researchers have learned to control the size of the particles by varying the processing conditions.

Depending on conditions, the new nanocrystals can be as much as four times more catalytically active per unit area than existing commercial catalysts. But since the new structures are more than 20 times larger than existing platinum catalysts, they require more of the metal – and hence are less active per unit weight.

“We need to find a way to make these nanocrystals smaller while preserving the shape,” Wang notes. “If we can reduce the size through better control of processing conditions, we will have a catalytic system that would allow production of hydrogen with greater efficiency.”

Production of the new crystals begins with polycrystalline platinum spheres about 750 nanometers in diameter that are electrodeposited onto a substrate of amorphous carbon. Placed in an electrochemical cell with ascorbic acid and sulfuric acid, the spheres are then subjected to “square wave” potential that alternates between positive and negative potentials at a rate of 10 to 20 Hertz.

The electrochemical oxidation-reduction reaction converts the spheres to smaller nanocrystals whose size averages 81 nanometers in diameter.

—John Toon

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Georgia High School Students Learn Job Safety Lessons

As part of an effort to increase job safety training and awareness among younger Americans, scientists from the Georgia Tech Research Institute (GTRI) have joined with the U.S. Occupational Safety and Health Administration (OSHA) and other groups to introduce health and safety training to Georgia high schools.

The aim: to try to ensure that young workers grasp job-safety basics before they ever reach the workplace.

GTRI instructors and others have already taught OSHA job-safety classes to three Georgia high schools, and more schools are scheduled to receive instruction. The effort stems from a 2006 agreement between OSHA, GTRI, Georgia schools and other groups to make safety and health training more available to the state’s students.

“Today, it’s an effort for many people in the workforce to remember safety basics – for example, to put their safety glasses on when working with chemicals,” says Michelle L. Dunham, a research scientist in the Occupational Safety and Health

Division of GTRI’s Electronic Systems Laboratory (ELSYS). “We want to make it automatic for young people joining the workforce to take those kinds of precautions.”

Students attend a 10-hour course that’s team-taught by OSHA and Georgia Tech instructors as well as industry representatives. The modular course covers general safety and health information as well as instruction pertaining to students’ areas of work specialization.

“There are lots of different modules, and depending on the school, they’ll vary,” Dunham adds. “We’ve started out teaching students going into the construction trades, but the course could be helpful to students in other study areas such as automotive and medical services.”

Those graduating receive the OSHA 10-hour card, which can give them an advantage with employers wanting to comply with OSHA regulations.

Dunham, an industrial hygienist, explains that the Georgia Tech Safety and Health Program also works directly with industry. Georgia Tech staff



Photo: Gary Meek

Students at Maxwell High School of Technology in Lawrenceville receive instruction in power-saw safety. Shown (l-r) are Ricky Child, GTRI’s Michelle Dunham, Marvin Hugging, Hunter Brandenburg, Brandon Reid and Justin Bennett.

perform on-campus training and consultation at the OSHA Training Institute Education Center, and also at job sites throughout Georgia and the Southeast.

Bringing the OSHA 10-hour course to high schools is one of the first results of the Georgia Youth Alliance, a 2006 outreach agreement between OSHA, GTRI, the Georgia Department of Education, the American Industrial Hygiene Association, the American Society of

Safety Engineers and the Construction Education Foundation of Georgia.

—Rick Robinson

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Marine Phytoplankton Changes Form to Protect Itself

A tiny single-celled organism that plays a key role in the carbon cycle of cold-water oceans may be a lot smarter than scientists had suspected.

In a paper published in June 2007 in *Proceedings of the National Academy of Sciences*, researchers report the first evidence that a common species of saltwater algae – also known as phytoplankton – can change form to protect itself against attack by predators that have very different feeding habits. To boost its survival chances, *Phaeocystis globosa* enhances or suppresses the formation of colonies based on whether nearby grazers prefer eating large or small particles.

“Based on chemical signals from attacked neighbors, *Phaeocystis* enhances colony formation if that’s the best thing to do for survival, or it suppresses the formation of colonies in favor of growing as small solitary cells if that’s the best thing to do,” says Mark E. Hay, Georgia Tech’s Teasley Professor of Biology. “These changes in form made nearly a 100-fold difference in the alga’s susceptibility to being eaten. It’s certainly surprising that a single-celled organism can chemically sense the presence of nearby consumers, identify those consumers and change in opposing ways depending on which consumers are present.”

The behavior could have implications for global climate change because *Phaeocystis* blooms play a key role in the carbon cycle of cold oceans, accounting for up to 85 percent of local productivity during some time periods. This complex defensive behavior also shows how environmental factors can affect even simple organisms, Hay notes.

The research was sponsored by the U.S. National Science Foundation and the U.S. Environmental Protec-

tion Agency.

Phaeocystis has two primary predators: small grazers such as ciliates, which prefer to eat small solitary cells that are four to six microns in diameter, and the larger shrimp-like copepods, which prefer to eat large, ball-shaped colonies.

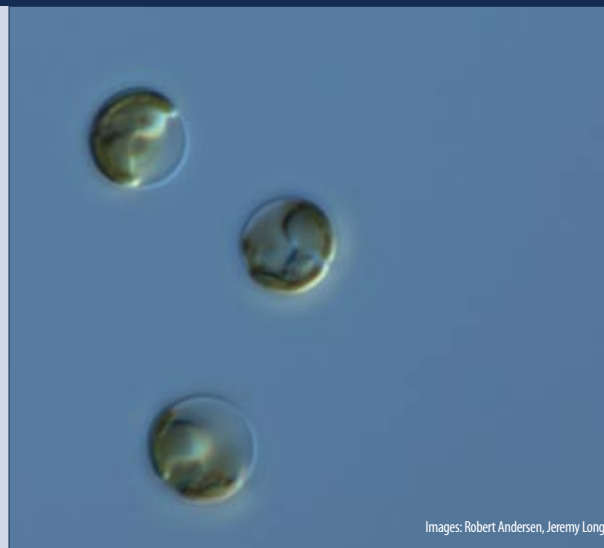
When copepods are attacking the phytoplankton, therefore, the best survival strategy of *Phaeocystis* is to form solitary cells. When ciliates are attacking, the best strategy is to form colonies that are too large for those predators to consume.

Lead author Jeremy D. Long, along with collaborators Gabriella W. Smalley, Todd Barsby, Jon T. Anderson and Mark Hay, found that’s exactly what *Phaeocystis* does. Chemicals that signaled attacks from copepods suppressed the formation of colonies by 60 to 90 percent, while signals from ciliates enhanced colony formation by more than 25 percent.

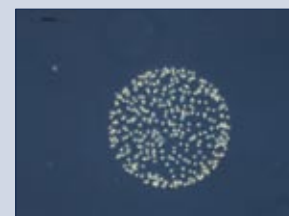
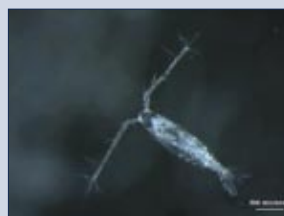
The transformations took place over periods of three to six days, and the overall size difference could be dramatic. “When one of these cells changes to the biggest colony form, although it takes a while, it’s like changing from a mosquito to 76 blue whales or 3,000 bull elephants,” Hay explains.

Defensive responses are often seen in higher plants, but this is believed to be the first report of such a complex and species-specific response in marine phytoplankton.

The response of *Phaeocystis* could be important to scientists studying climate change because the predator that ultimately consumes the phytoplankton determines the fate of the carbon it contains. If eaten by copepods, for example, the carbon becomes part of fecal packages that sink into the deep ocean where a portion of that carbon



Images: Robert Andersen, Jeremy Long



Phaeocystis suppresses colony formation (above, right) in the presence of chemical signals from copepods (above, left) and remains as small, solitary cells like these (top) that are only a few micrometers in diameter.

is sequestered – thereby reducing atmospheric carbon dioxide, a leading greenhouse gas. If consumed by smaller creatures like ciliates, less of the carbon sinks to the deep sea and more remains in the surface waters.

Experimentally, the researchers attempted to separate the chemical signals from the actual predators. They grew *Phaeocystis* in the presence of either ciliates or copepods. They then filtered out both the phytoplankton and predators, leaving only water containing the chemical signals of attack.

Water samples containing signals from the two predators were then separately introduced into *Phaeocystis* cultures that had not been attacked. The scientists then studied how the different chemical signals affected the percentage of

Phaeocystis living in colonies or as solitary cells. Finally, they examined whether this response affected how much the predators ate to determine if the change conferred a survival advantage.

“We found that these organisms were making the right choice,” Hay adds. “They were shifting to the shape that made them largely immune to whichever predator was attacking, and this shift suppressed either the feeding or growth and reproduction of the consumer to which they were responding.”

–John Toon

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Two-Photon Absorbing Molecules Allow Polymer Features 65 Nanometers Wide

Producing three-dimensional polymer line structures as small as 65 nanometers wide just became easier with the development of new two-photon absorbing molecules that are sensitive to laser light at short wavelengths, allowing researchers to create them without highly sophisticated fabrication methods.

Fabricating such small features normally requires expensive electron beam or extreme ultraviolet lithography equipment. However, using a technique called 3-D multi-photon lithography simplifies the process and reduces the cost. The technique could compete with existing processes for fabricating nanoscale electronic, photonic and microfluidic devices.

"Being able to obtain line widths down to 65 nanometers, which is substantially below prior published work of 100 nanometers, opens up new applications for multi-photon lithography," says Joseph W. Perry, a professor in the Georgia Tech School of Chemistry and Biochemistry and the Center for Organic Photonics and Electronics.

The technique scans a laser beam across a substrate coated with a polymer resin containing a unique dye to create a hardened polymer structure. The laser writing process takes advantage of the fact that the chemical reaction of cross-linking occurs only where molecules have absorbed two photons of light. Since the rate of two-photon absorption drops off rapidly

with distance from the laser's focal point, only molecules at the focal point receive enough light to absorb two photons.

The fabrication method and dye were described in the journal *Optics Express* in April 2007. The research was supported by the Office of Naval Research APEX Consortium and the National Science Foundation.

Seth Marder and Stephen Barlow, also researchers in the School of Chemistry and Biochemistry and the Center for Organic Photonics and Electronics, synthesized the unique molecule called DAPB, 4,4-bis(di-n-butylamino) biphenyl, used to initiate the chemical reaction leading to the hardening of the polymers when exposed to laser light.

The molecule is about 10 times more efficient at absorbing light by two-photon absorption than commercial ultraviolet photoactive materials. That efficiency allowed Perry and graduate students Wojciech Haske and Vincent Chen, research scientist Joel Hales and postdoctoral associate Wenting Dong to create 3-D patterns with nanoscale lines at light intensities low enough to avoid damaging the polymers.

For the experiments, a film of the polymer resin containing DAPB was formed. When the film was exposed to the focused laser, DAPB was excited and triggered cross-linking, leaving the insoluble scanned structure on the surface of a substrate after it was placed in a developer solution.

Since Perry uses a computer program to control where the Ti: Sapphire-pulsed laser scans, the polymers can be cross-linked in any pattern – including 3-D stacks of straight lines that are connected. The laser beam is turned on to expose lines of polymer and off when no line should be drawn.

Conventional lithography involves creating a specific pattern on a mask for each new layer, exposing each layer to light and then developing it. With this new technique, three-dimensional layered nanostructures can be created simply by having a computer program scan a different pattern for each layer. Mask templates become unnecessary – and the coating, exposing and developing processes only have to be conducted once.

"We can write very small lines and create stacked-up grids of lines called photonic crystals," explains Perry. "This work shows that we can fabricate functional photonic micro-devices with tailored transmission capabilities."

It takes only 10 minutes to create a 20-micron-by-20-micron structure with 30 layers, Perry adds. He envisions using this technology to create compact micro-spectrometers on a chip for use in telecommunications and sensors. It may also be used as a compact way to separate the multiple wavelengths traveling through a fiber optic cable.

This type of simple, table-top

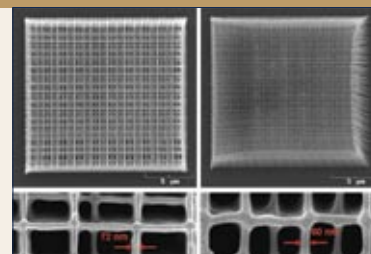


Image: Joe Perry | Photo: Gary Meek



Professor Joe Perry and researcher Vincent Chen adjust optics (above) in research that has produced 3-D polymer line structures as small as 65 nanometers wide, which are useful in creating photonic crystals (top).

technology may also be useful to fabricate customized types of circuits with many layers, which would be extremely expensive with standard methods because each layer would require a special mask.

"With the combination of the right molecule and short wavelength light, we've demonstrated that we can obtain nanoscale features. We're at 65 nanometers now and we're still trying to go smaller," says Perry.

– Abby Vogel

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Gene Thought to Assist Chemotherapy May Help Cancer Thrive

A gene thought to be essential in helping chemotherapy kill cancer cells may actually help them thrive.

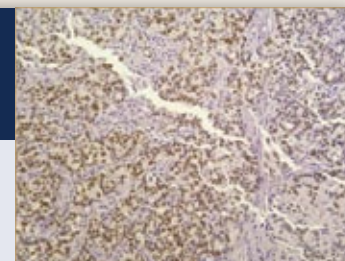
In a new study of chemotherapy patients, scientists at the Georgia Institute of Technology and the Ovarian Cancer Institute found that 70 percent of subjects whose tumors had mutations in the gene p53 were still alive after five years. Patients

with normal p53 displayed only a 30 percent survival rate.

The findings raise the possibility of a new strategy for fighting cancer – namely, developing drugs to disable the functioning of this gene in the tumors of patients undergoing chemotherapy. The results appeared in May 2007 in the journal *PLoS ONE*.

"P53 has long been recognized as a key player in directing chemotherapy-damaged cancer cells to self-annihilate, but less attention has been paid to p53's role in repairing damaged cells," says John McDonald, chair of Georgia Tech's School of Biology and chief research scientist at the Ovarian Cancer Institute.

When a cell is malfunctioning or



Dark stains indicate that the gene p53 is mutated in these ovarian cancer cells.

injured, the gene p53 is called into action and tries to repair the cell. If the cell can't be repaired, p53 starts a process known as

apoptosis that kills the cell. It is p53's role as one of the genes involved in initiating cell death that has led cancer researchers to believe that the gene is essential to successful chemotherapy. The idea is that p53 assists in killing the cancerous cells that the chemotherapy treatment injures.

But in this latest trial, Georgia Tech researchers found that p53 may be a "double-edged sword." Chemotherapy patients whose tumors had a mutated p53 gene that didn't work had a much better survival rate than those who had normal p53.

In the study, researchers compared the gene expression profiles of malignant and benign ovarian tumors. Some of the cancer patients had been treated with chemotherapy prior to surgery, and some had not.

The researchers found that the gene expression profiles of the

tumors clustered the chemotherapy-treated patients into two groups: those whose profiles were similar to cancer patients who had not been treated with chemo and those whose profiles were similar to patients with benign tumors.

As they continued their analysis, they found that the main difference between the groups' genetic profiles was the gene p53. While both groups had roughly the same amount of the protein encoded by p53, the cancer group had mutations in their p53 that caused the gene's corresponding protein not to function. The benign group's p53 was normal.

Five years later, only 30 percent of the chemotherapy cancer patients clustering in the benign group were alive, while 70 percent of those clustering in the cancer group were still alive. The stage of cancer at the time of surgery had no correlation

to who survived and who didn't. What did seem to have an effect was whether p53 was working or not in the chemotherapy-treated tumors.

A standard belief in cancer research is that a working p53 is essential in helping chemotherapy patients because it turns on the killing mechanism for the cells that were damaged by chemo. But McDonald points out that p53 can also help repair damaged cells. If p53 is repairing cancer cells, that may lead to cancer recurrence.

"We think p53 may actually help some cancer cells make a comeback," he says. "Based on our results, we propose that p53 may help repair some of the cancer cells damaged by chemotherapy — leading to tumor recurrence and explaining the higher mortality rate of patients whose tumors had a functioning p53. If we are correct, inhibiting p53 in tumors being treated with chemotherapy

may substantially improve patients' long-term survival."

In addition to McDonald, the research team consisted of: Benedict Benigno, gynecologic oncologist and founder of the Ovarian Cancer Institute; Lilya Matyunina, Erin B. Dickerson, Nina Schubert and Nathan J. Bowen from Georgia Tech and the Ovarian Cancer Institute; Sanjay Logani from Emory University; and Carlos Moreno from Emory's Winship Cancer Institute.

The research was supported by the Georgia Cancer Coalition, the Georgia Tech Research Foundation, the Robinson Family Foundation and the Larry and Beth Lawrence Foundation.

— David Terraso

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Companies from Science & Technology Incubator Attract \$1 Billion

Companies associated with Georgia Tech's science and technology incubator have raised more than \$1 billion in venture capital since 1999 — and in 2006 accounted for 10 of the top 25 venture deals in Georgia, including the two largest.

The incubator, the Advanced Technology Development Center (ATDC), has turned out 112 science and technology companies since 1986 — including 31 that have been represented on the public markets through initial public offerings or acquisitions.

At a May 10 event held to showcase the incubator's companies, ATDC "graduated" six early-stage firms — three Internet companies, two semiconductor firms and a developer of homeland security technology. Together, those six early-stage firms raised more than \$50

million while in the incubator.

"ATDC is a source of exciting deal flow, and we have invested in many ATDC companies," says Fred Sturgis, managing director of the \$4-billion Miami-based venture capital firm H.I.G. Ventures. "ATDC attracts leading entrepreneurs in Georgia and increases the probability of success for its companies."

The \$1 billion raised by ATDC companies included 160 deals in 75 companies from 138 venture investors. The average deal size was \$6.7 million, though funding amounts varied, with 32 companies raising less than \$5 million and 10 raising more than \$25 million. The \$1 billion includes funds raised by companies throughout their growth, including their time in the incubator and after they graduated.

"ATDC is an invaluable resource to Georgia, as the leading organization for advancing business incubation and entrepreneurship," says Susan O'Dwyer, national director of venture capital research for PricewaterhouseCoopers. "Over its 26-year history, ATDC's staff has provided hundreds of entrepreneurs at early-stage companies with the right experience, business planning advice and networking resources needed to grow their companies."

The incubator is an example of how universities are making an increasingly important contribution to local and state economies, notes Wayne Hodges, vice provost for Georgia Tech's Enterprise Innovation Institute — ATDC's parent organization.

"Through ATDC, Georgia Tech is helping build a strong com-



Photo: Gary Meek

ATDC Showcase and Open House.

munity of experienced science and technology entrepreneurs," Hodges says. "The billion-dollar celebration demonstrates that the strategy of supporting the development and growth of startup companies has paid off for the state."

— John Toon

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