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Features work by Punit Kohli, Samir Aouadi, Shane Stadler, Boyd Goodson, Yong Gao, Amer AbuGhazaleh, and other researchers; special cover story on nanotechnology research.

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PERSPECTIVES

Fall 2006

Research and Creative Activities

Southern Illinois University Carbondale

MAKING IT NEW

A Nanotechnology Research Sampler

ALSO: Corralling Qubits ✚ Eco-nomics ✚ Grade A

In 1996 *Perspectives* had a special theme issue on materials science research at SIUC. A decade later, materials science continues to be one of our strengths, with a growing emphasis on nanotechnology. Nanomaterials have special properties and special uses because they are designed on such a small scale. This research area has generated many patent applications at the University recently. Hence we have devoted half of this issue to covering a number of relatively new nanotech projects.

Several of the researchers featured here have received prestigious CAREER awards from the National Science Foundation—awards that fund not only research, but also undergraduate curriculum innovation. We are doubly pleased that the NSF recently chose SIUC as a Research Experiences for Undergraduates site in materials science (see page 14).

In the REU program, select universities introduce promising undergraduates from across the country to laboratory research in specific areas. The program's goal is to encourage more students to enter graduate studies in science. Numerous SIUC faculty in chemistry, physics, and engineering mentored REU students over the summer; you will see some of these students pictured in our cover article.

Readers can look for more coverage of nanotech projects in the future. As this issue was going to press, for example, we learned that SIUC physicist Andrei Kolmakov is receiving national attention for his work on nanoscale electronic "noses"—tiny sensors made of semiconducting nanowires that can "sniff out" particular gases. Chips loaded with such nanowires could be useful in many areas—homeland security being perhaps one of the most pressing.

It's a changing world, and SIUC is part of the mix.

John A. Koropchak

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Vice Chancellor for Research and Graduate Dean

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Perspectives • Fall 2006

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For information about the research program at SIUC, visit www.siu.edu/~ovcr, or contact John A. Koropchak, Vice Chancellor for Research and Graduate Dean, (618) 453-4551, koropcha@siu.edu, or Prudence M. Rice, Director, Office of Research Development and Administration, (618) 453-4531, pmrice@siu.edu.

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PERSPECTIVES
FALL 2006
RESEARCH AND CREATIVE ACTIVITIES
SOUTHERN ILLINOIS UNIVERSITY CARBONDALE

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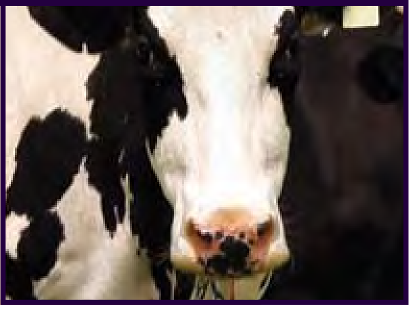
Cover Story

Nanotechnology involves designing materials and structures at the atomic or molecular level. The scale is so small, it's hard to imagine—or image. Yet the possibilities are great.

In our special cover story we feature a sampling of current nanotech projects at SIUC. This basic research has potential applications in computing, electronics, medical imaging, biosensing, the aerospace industry, and more. This is not the first time we've featured materials science at the nano level—and it certainly won't be the last.

Feature Story

An SIUC dairy specialist wants to create a niche market by cutting the saturated fat content of milk while boosting its levels of healthful fatty acids. He's shown it can be done—and it may be a good option for small, family-owned dairy farms.



PROTEIN I.D.

Genes are one thing, but SIUC scientist Luke Tolley says proteins are where the rubber meets the road in the fight against cancer.

Far more complex than their biological counterparts, proteins do the work assigned to them by DNA, such as telling a cell when and how to reproduce itself. For this reason, many researchers believe protein malfunctions may be at the root of cancer, which involves abnormal cell growth.

Scientists would like to be able to separate and identify all of the proteins present in cells and to compare the protein makeup of healthy versus abnormal cells. But that's a tall order. A typical cell in the human body, for instance, can contain as many as half a million proteins, some in high concentrations and some in extremely low concentrations. Furthermore, the protein content of a cell fluctuates depending on body processes (such as metabolism).

Luke Tolley, assistant professor of chemistry, and Cal Meyers, distinguished professor emeritus of chemistry, recently won a two-year, $248,000 grant from the National Cancer Institute to develop a new and improved instrument for separating and identifying proteins in complex mixtures like cell solutions.

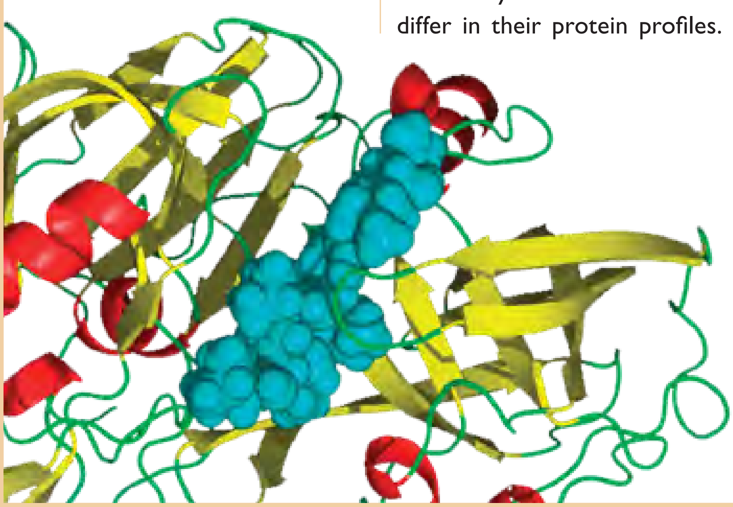
The goal is to get a much more complete picture of the protein profiles of cells. "This is a new tool you can use to look at things you haven't been able to look at before," Tolley says.

Tolley's technology is called "dynamic isoelectric focusing" of protein molecules. With seed money provided by the University in 2005, he built a working prototype of the device. With the NCI funding, he and his doctoral students are now working on an improved prototype.

"The [new] device does better separation [of proteins] much faster, with results that are more reproducible," Tolley says.

Simply being able to run more separations faster—his device takes only about 30 minutes to run a separation—will allow scientists to do more valuable research. And the new device is relatively inexpensive and easy to fabricate, adding to its appeal.

Healthy and cancerous cells differ in their protein profiles.



▲ Luke Tolley demonstrates how his dynamic isoelectric focusing instrument can be used in conjunction with a microscope. The new device should make it much easier for researchers to separate and identify proteins, aiding in the fight against cancer.

For example, cancer cells tend to contain more types of proteins, some of which have undergone modifications. If a given protein is absent in healthy cells but found in cancerous cells, it could be either a cause or a byproduct of that cancerous state.

Scientists need to determine which is the case. Tolley's device will allow specific proteins to be extracted from cancer cells and introduced into healthy cells so that their effects can be studied.

The instrument uses tiny, incremental differences in voltages to isolate proteins in samples held in glass tubes no thicker than a human hair. So far, Tolley has succeeded in isolating about 1,100 proteins from a mix. Ultimately he will couple the device to one or more existing technologies to boost the number of proteins that can be isolated potentially into the millions—and do it far more reliably than is now possible.

As proof of concept for the NCI grant, Meyers, who has developed some unusual anticancer compounds, will use the instrument to analyze prostate cancer cell proteins before and after exposure to those compounds, looking for key differences that might lead to improved treatments.

"The goal is to figure out what those [protein] differences mean to cancer research," Tolley says. "That's the next step." ✚

*The first research paper about this new technology was published in the journal **Analytical Chemistry** this past summer. More info: Dr. Luke Tolley, Dept. of Chemistry and Biochemistry, ltolley@chem.siu.edu.*

—Tim Crosby; Marilyn Davis

RIVER PIRATES

He undoubtedly didn't resemble Blackbeard or Jack Sparrow, and the sea was not his lair. But he was a pirate nonetheless, and his reign helped to stoke folklore that persists to the present day.

His name was Capt. Samuel Mason, and he operated along the Ohio and Mississippi Rivers in the late 1700s and early 1800s. He was the worst of the worst, according to SIUC archaeologist Mark Wagner and U.S. Forest Service archaeologist Mary McCorvie, who recently contributed a chapter on river piracy to *X Marks the Spot: The Archaeology of Piracy* (University Press of Florida, 2006).

"There's a lot of folklore about piracy on the Ohio River, and most of what's written isn't true," Wagner says. "But Samuel Mason did bad, bad things on the Ohio for a period of about 20 years."

Mason began his career of thieving, robbing, and killing in eastern Tennessee. Later he and his gang attacked river vessels—mainly flatboats carrying emigrant families or trade goods downriver—along the Ohio in the vicinities of present-day Henderson, Ky., and Cave-in-Rock, Ill. He ultimately moved his operations to Spanish territory along the lower Mississippi, where he was captured.

Piracy on the Ohio and Mississippi "appears to have started in the late 18th century, as the dramatic increase in river traffic to New Orleans made this form of banditry economically profitable," Wagner and McCorvie write. Pirates had plenty of choices for good hangouts, since the surrounding countryside was so sparsely settled. But as the population grew, so did law enforcement, and the heyday of river piracy was over by about 1830.

Interestingly, however, "archaeologists have yet to identify a single definite pirate-related archaeological site in either the Ohio or Mississippi River valleys," Wagner and McCorvie write. Instead, the main evidence for piracy comes from accounts in travel diaries, court transcripts, and other government papers.

The two scholars have begun to study whether assemblages of artifacts from various sites can help archaeologists distinguish ordinary encampments from pirate camps. Finding and excavating the wrecked remains of flatboats and other vessels also may shed some light on river piracy. Both are long shots, archaeologically speaking.

Digging in storerooms, rather than in the dirt, may prove the most fruitful way to learn more about the activities of river pirates along the Ohio and Mississippi, Wagner and McCorvie say. They "suspect that many additional but as yet unexamined documents relating to Ohio and Mississippi piracy exist in Spanish, French, and American archives"—waiting to help scholars separate fact from fiction.

More info: Dr. Mark Wagner, Center for Archaeological Investigations, mjwagner@siu.edu.

—Marilyn Davis

CULTURE CLASH

Three centuries ago, a Spanish-led army camped on the edge of a lake deep in Central America, its soldiers assembling a boat for an assault on a native island capital.

This past summer, two SIUC experts on Maya civilization once again ventured into the area to begin deciphering an archaeological site they think includes that Spanish encampment.

Anthropology professors Pru Rice (also associate vice chancellor for research) and Don Rice (also associate provost) traveled to the Petén region in northern Guatemala with a team of students to start excavating a settlement once inhabited by Maya peoples known as the Itzá.

From about 1200 A.D. onward, the Itzá capital was sited on an island in a large lake called Lake Petén Itzá. The region around this lake was a center of late Maya culture. When the capital fell to the Spanish in 1697, the Itzá Maya became the last indigenous kingdom in the New World to go under the control of Europeans.

Since the 1970s, the Rices and their students have been excavating the remains of settlements around Lake Petén Itzá, work that has shed much light on Maya civilization immediately before and after Spanish contact.

The new site (shown below) is on the lake's western edge and seems to contain remnants of a Spanish encampment. If the Rices are right, this is the place where Spanish soldiers rebuilt a disassembled warship that they hauled through the jungle by mule to use during their island conquest.

Field work will concentrate on the encampment and the Itzá settlement surrounding it, which consists of about 450 mounds, rectangular structures, and pyramid-shaped enclosures.

The research is being funded by a three-year, $100,000 grant from the National Endowment for the Humanities.

*More info: Dr. Pru Rice, Dept. of Anthropology, price@siu.edu. **Perspectives** featured the Rices' research in our Spring 1997 cover story.*

—Tim Crosby

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Alarmed about the scope of population declines and extinctions of frogs, toads, and other amphibians, a group of 50 scientists, including SIUC zoology professor Karen Lips, has called for formation of an international Amphibian Survival Alliance with an initial budget of at least $400 million.

Such an alliance is urgently needed, the scientists say, to coordinate conservation efforts, set up regional centers for disease research and captive breeding, create databases, and train personnel in countries that have little expertise in this area.

The call to action was published in the July 7, 2006, issue of *Science.* One-third of all amphibian species, including entire groups of species, are threatened, the scientists say, and the problem involves "nearly all regions of the planet." Because the threat is global, conserving amphibian biodiversity will take a global effort, they say.

Lips was one of the first scientists to document massive die-offs of frogs and toads in the highlands of Costa Rica and Panama. (Her work was featured in a cover story in *Perspectives* in 1999.) There, the prime culprit is a rapidly spreading fungus that has also affected amphibians on other continents.

Based on that research, Lips and her colleagues estimate that within six months of the fungus's arrival in a new area, about half of the amphibian species present there and 80 percent of individual animals will succumb to it. Global climate change may be enabling the fungus to spread so rapidly and have such extreme effects, the scientists note.

Other threats to amphibians include habitat loss and pollution.

—Marilyn Davis

AFTER THE STORM

Hurricane Katrina was the costliest and most destructive storm to hit the United States. Nearly a year later, the struggles of Gulf Coast residents continue.

New anthropology professor Roberto Barrios (below), whose work focuses on the social aftermath of natural disasters, spent two months this past summer living in a FEMA trailer in a largely Vietnamese neighborhood on the east side of New Orleans.

His purpose? To record the sociopolitical relations between government agencies and displaced residents, with the aim of helping agencies better respond to disasters.

"I am interested in the policies being devised for recovery efforts and the impact on the people" they're supposed to help, Barrios says.

"The premise I'm working on is that when a policy is created, it inevitably has to assume things about people and societies. My research has shown those assumptions are often incorrect, and that causes social crises."

Eric Dangoy, a master's student in anthropology, joined Barrios for two weeks in June, attending protests staged by community residents and interviewing city council members working on the reconstruction process.

Barrios, who stayed in New Orleans until the end of July, will be presenting the pair's findings later this academic year.

"Recovery is slow, disorganized, and filled with frustration for residents," he says.

"Families and business owners are going about reconstruction on their own and the local governments are tying their own hands [with] their own bureaucratic policies. The answer is to give neighborhood associations veto power over policies made by larger government agencies." ✚

Roberto Barrios also held a Fulbright Fellowship in 2000 to report on the nutritional status of children in Honduras after Hurricane Mitch devastated the region. More info: Dr. Roberto Barrios, Dept. of Anthropology, rbarrios@siu.edu.

—Sun Min

ECO-NOMICS

J. B. Ruhl's geography dissertation defense this past summer was an unusual affair. The student was a tenured professor, and his dissertation is already under contract with Island Press, a publisher of environmental books.

On the law faculty at SIUC from 1994 to 1999, and now at Florida State, Ruhl is a nationally recognized expert on environmental law and policy. His doctoral work focused on the economic benefits we gain from sustainable ecosystems, and how economic approaches are needed to preserve them.

Ecosystem "services," which range from pollination to climate regulation, have substantial economic value to society. But since those services don't appear on any ledger sheet, our laws and markets aren't geared to take them into account.

As Ruhl explains, we can estimate the value of the timber that a tract of forest could provide if it were logged. But we can't readily estimate the economic value of ecosystem services provided by an intact forest, such as erosion control, carbon dioxide absorption, and recreational value.

"People who own natural capital in the form of services—for example, wetlands providing flood control—can't benefit from it economically, so it's easier to make decisions to destroy it—for example, to fill the wetlands," Ruhl says. "If we can better account for the economic value of these resources, we can make better public and private decisions about how to use them."

Modernizing property rights, developing smarter regulations, offering economic incentives to keep land undeveloped, and changing social norms must all be part of the solution, he says.

As a law professor at SIUC, Ruhl began taking geography courses to gain a more comprehensive perspective on environmental issues. His dissertation makes the case that legal experts and policy makers need to work with geographers, ecologists, and economists to learn "what's happening on the landscape" and what the economic effects of environmental decisions are likely to be.

In many cases, he says, we simply don't have the data to know "what we're losing in terms of ecosystem services."

Take wetland mitigation. Federal law stipulates that if wetland acreage is destroyed for development, a comparable wetland must be created within a certain geographic radius. But to Ruhl's dismay, no agency had compiled data tracking the distances between destroyed wetlands and created wetlands.

After a lot of digging, he discovered that the wetlands being lost in coastal urban areas in Florida are being "mitigated" by wetlands miles away in rural areas. The urban areas "are losing wetland services that aren't being replaced," he says.

To remedy that, subsidies could be used to encourage near-site mitigation and taxes used to penalize far-distant mitigation. Or the regulations could be rewritten. In any event, says Ruhl, "Our decision making needs to be more complete."

Some positive changes are in the offing. The Army Corps of Engineers and the U.S. Forest Service say they will now consider ecosystem services in their projects and management plans.

The courts also seem more willing to take ecosystem services into consideration in property law. One judgment, for example, barred a private landowner from filling in a wetland. Why? The court held that the action would create a public nuisance by removing flood protection for the surrounding population.

And along the Florida Gulf Coast, Ruhl says, "land use planning has changed significantly" since the recent hurricanes. That's a case of social values changing.

"Victims of Hurricane Katrina get it now," he says. "They are willing to pay for coastal wetlands protection, coastal dunes protection. If there's any silver lining to Katrina, it's that more people now grasp the importance of preserving ecosystem services.

"Will it translate into changes in common law vis-à-vis property rights? It could—especially if you argue plain old economic value to courts, rather than ethics."

*J. B. Ruhl's research on the Endangered Species Act was featured in the Fall 1996 **Perspectives.** He may be contacted at jruhl@law.fsu.edu.*

—Marilyn Davis

CORRALLING QUBITS

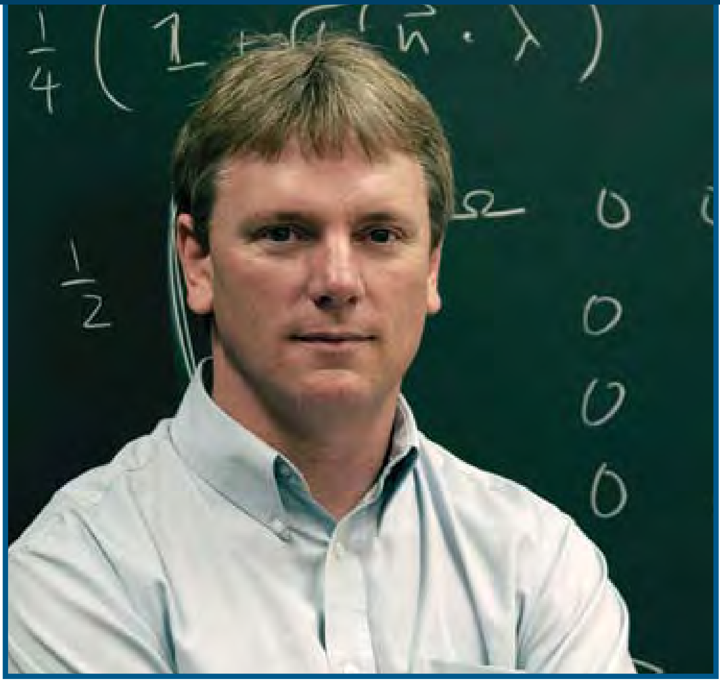
Smaller is the watchword when it comes to manufacturing the devices that make computers work. Scientists would like to make a quantum leap in miniaturization—and in computing power—by harnessing atoms to carry out calculations.

Classical Newtonian physics governs atoms en masse and describes the everyday cause-and-effect we observe in physical objects. But individual atoms and their constituents, such as electrons, obey the laws of quantum physics, where quirky behavior results as these particles jump back and forth between different energy states.

For decades, researchers have theorized that quantum effects could open the door to immensely powerful computers, if scientists can master the inherent complexities of this infinitely small world.

An SIUC physicist is working toward that day. Assistant professor Mark Byrd has received a five-year, $400,000 CAREER award from the National Science Foundation to study some of the fundamental problems in developing a working quantum computer.

Classical computers work by having a set of switches that can be in one of two positions: on or off, 1 or 0. But quantum computers would not be limited to this binary language. Instead, they would rely on the ability of atoms to represent a one, a zero, or virtually limitless positions in between—"qubits," rather than bits. A set of qubits could work on many calculations simultaneously. That parallelism would make quantum computers far more powerful than classical computers.



▲ **Physicist Mark Byrd is studying error correction methods for quantum computing.**

Such power would have broad application in the fields of security and encryption, in searching large databases, or in simulating quantum-mechanical systems. The latter capability would be immensely useful in chemistry, biology, physics, and other fields.

But first researchers must overcome many obstacles.

They have taken the first steps, stringing together 10 qubits that can perform calculations. But an actual quantum computer would involve at least several hundred such devices working in concert, Byrd says.

"The idea is for it to be scalable to larger systems. Each time we make a step we get to learn more about these systems and how they behave.

"But they do make errors," he says. "All of these systems are very susceptible to errors."

Byrd will investigate several ways to eliminate or compensate for the errors inherent in quantum computing. One such method will involve constructing codes very much like those written for classical computers to detect and correct errors.

He also will look at encoding the information carried by the qubits to make it less susceptible to outside interference or "noise," and ways to manipulate the "spin" of electrons to control that phenomenon.

Although much of Byrd's work is theoretical (equation-driven), he will work with experimentalists during parts of the grant project. ✚

More info: Dr. Mark Byrd, Dept. of Physics, mbyrd@physics.siu.edu.

—Tim Crosby

TO THE NEXT POWER

An SIUC mathematics professor is furthering the cause of civil rights by helping high school and college students learn to work with younger minority students on their math skills.

Gregory Budzban recently received a grant from the Young People's Project Inc. to develop methods for training the high school and college students as "math literacy workers." The grant covers the cost of creating training methods, materials, and workshops aimed at producing up to 500 such workers.

The Young People's Project grew out of the Algebra Project, the brainchild of civil rights–era activist Robert Moses, an innovative math educator who created the program to improve minority students' math performance. Budzban met Moses in 2001 when he invited him to speak at SIUC. The two have collaborated ever since. Moses' daughter, Maisha Moses, who is finishing her master's degree in math at SIUC this fall, works with Budzban on several math literacy initiatives, including the grant.

Previously, Budzban and Robert Moses teamed up on a $700,000 National Science Foundation grant titled "Raising the Floor," which focused on ninth-graders and incorporated Budzban's work on the so-called "Road Coloring Problem" into the Algebra Project's approach. Their efforts used innovative games to demonstrate the principles of classic math problems, using peer instructors who were just a year or so older than the students.

"The approach we use is to immerse students in what we call mathematically rich experiences," Budzban says. "The Road Coloring Problem can be approached like a game. But it's a game that can operate on many different levels of math. Part of our work has been tailoring the approach to the problem to the age of the students."

This fall and winter, Budzban and Maisha Moses are working on tailoring another game—The Flagway Game—to different age levels, as well as starting "math leagues" at several sites around the country. "There is very deep math in each of these problems that can be made accessible to a full range of students," says Maisha Moses, who was instrumental in obtaining the grant. "The math league will be like Little League, except they'll be doing math instead of baseball."

For both Budzban and Maisha Moses, improving math performance among minority students is crucial in today's economy, which hinges on technological and scientific skills.

"[If] students come to the University without the proper math preparation, roughly half the programs are closed to them. Many of those areas are among the fastest-growing professions," Budzban says.

Maisha Moses agrees that giving young people options is the goal. "I want everyone to have the chance at an education that provides a full range of choices," she says.

More info: Dr. Gregory Budzban, Dept. of Mathematics, gregb@math.siu.edu; or see www.algebra.org.

—Tim Crosby

Melvin Weaver and Demetrica Gorden (far left and right, respectively), high school teachers from Jackson, Miss., worked with Greg Budzban and Maisha Moses this past summer on innovative ways to teach ninth-graders higher math concepts.

HELPING QUITTERS

Why do people smoke? What happens when they try to quit?

How does it affect the mind and body? Who benefits the most from different quit-smoking methods such as nicotine patches and the medication Zyban?

The National Institute on Drug Abuse has awarded SIUC psychology professor David Gilbert a $2.8 million grant to search for answers.

"We're always trying to find better ways to help people quit smoking," says Gilbert, who is internationally renowned for his work on the psychological and biological bases of nicotine use.

Gilbert established the Smoking Laboratory at SIUC in 1985 to study the psychological and brain mechanisms involved in smoking and quitting smoking. By studying subjects' brain-wave patterns and genetics, he and his large team of student assistants have explored the relationships between nicotine addiction, emotions, and concentration, assessing which smokers are most likely to be able to quit by using behavioral techniques, the nicotine patch, or other aids.

The NIDA award is Gilbert's fourth major smoking-cessation grant. Over the next five years, Gilbert's team will study 220 men and women as they quit smoking over 67 days. They will evaluate the effects of using Zyban versus using a nicotine patch, looking at how the two act on the brain and how they affect participants' concentration and mood.

Scientists will use the findings to come up with new ideas for helping smokers quit permanently and improving current products on the market.

David Gilbert's research on nicotine, mood, and quitting smoking was featured in ***Perspectives'*** *cover story in Spring 1995. More info: Dr. David Gilbert, Dept. of Psychology, dgilbert@siu.edu.*

—Sun Min

KUDOS

English professor Kevin Dettmar has received a $118,892 grant to direct a National Endowment for the Humanities Summer Seminar for College and University Teachers in 2007. The six-week session will bring 15 teachers together with Dettmar in Dublin, Ireland, to study novelist James Joyce's masterpiece, *Ulysses.*

Ruth Anne Rehfeldt, associate professor with SIUC's Rehabilitation Institute, has been named editor of *The Psychological Record,* a national peer-reviewed journal that publishes articles on theory, research, historical developments, and current findings.

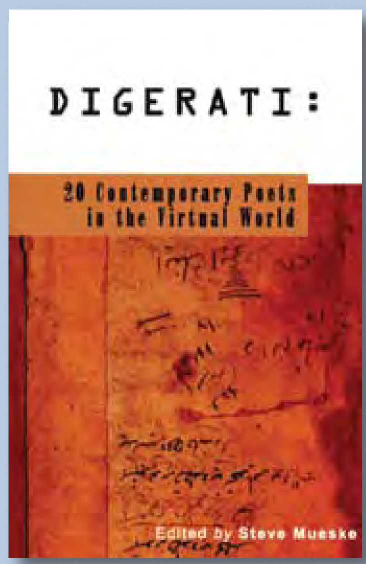
Physiologist Jena Steinle has been awarded a five-year, $750,000 grant from the Juvenile Diabetes Research Association to continue her investigations into whether a particular drug used in asthma treatment may offer a way to prevent diabetic retinopathy. A patent application has been filed on the potential advance.

Physicists Naushad Ali and Shane Stadler have received a four-year, $620,000 grant from the U.S. Department of Energy to optimize and analyze alloys that they have developed that are better than any others to date at producing a refrigeration effect without the use of compressed gases. Look for an article about this research in the Spring 2007 issue of *Perspectives.*

Y. Paul Chugh, a professor of mining and mineral resources, will spend time this fall as a Fulbright Senior Specialist at the top mining institution in India. Chugh will gather input from the nation's academic and mining industry leaders to further develop the Indian School of Mines' environmental science and engineering programs. An internationally known coal researcher, Chugh also will help the institution expand its research efforts.

In December, Chugh will deliver a keynote lecture on the future role of coal around the globe to the International Coal Congress in New Delhi.

Poet Michael Meyerhofer, a new lecturer in English who earned his M.F.A. in creative writing from SIUC this past summer, was among only a score of younger poets whose work was chosen to appear in the anthology *Digerati: 20 Contemporary Poets in the Virtual World* (Three Candles Press, 2006). This year Meyerhofer also won the inaugural Liam Rector First Book Prize for Poetry, sponsored by Briery Creek Press, for his poetry collection *Leaving Iowa.* The book will be published this fall.



A University Museum exhibit curated by Linda M. Smith, a doctoral student in anthropology, has won the prestigious Leadership in History Award from the American Association for State and Local History. The honor was for the fall 2004 multimedia exhibit "Words, Wood & Wire: The History of Southern Illinois as Told Through Folk Songs and Musical Instruments." Smith is an ethnomusicologist and musician; her exhibit highlighted the research of David McIntosh, a late music professor who recorded the folk music of Southern Illinois in the 1930s–1950s.

Two graduate students in zoology, Andrew Trimble and Amanda Harwood, have been awarded prestigious $60,000 STAR Fellowships from the Environmental Protection Agency. Both are working in the lab of zoologist Michael Lydy, who investigates the effects of various water pollutants on aquatic organisms. A third STAR Fellow at the University, Brian Benscoter, is a doctoral student working with plant biologist Dale Vitt.

Plant scientist Bryan Young has received $880,000 from Monsanto Co. for research on agricultural weed management and the use of Roundup Ready crops (those engineered to be resistant to the company's Roundup herbicide). The work, part of a four-year, six-state study, will look at farmers' weed management practices and the benefits and risks of Roundup Ready cropping systems. Issues will include long-term ecological suitability.

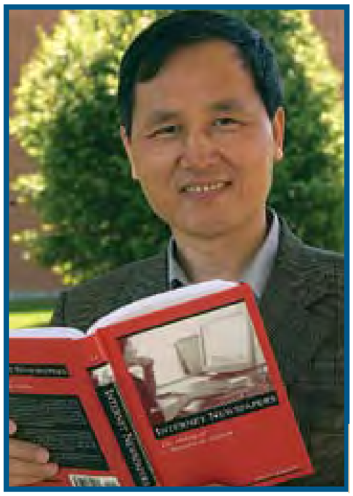
ONLINE NEWS

In 1994, the year Xigen Li left his homeland, a worldwide virtual revolution was in the making. It was the fledgling Internet, and Li soon realized that it had the potential to fundamentally change the way people received information from the media.

A veteran of both print and broadcast media in China, Li (below) came to the United States to pursue a doctorate in mass media—just at the time that news organizations were making their tentative debuts online.

"Because it was so new, I was at the same level as everybody else with the Internet," says Li, now an assistant professor of journalism at SIUC. "But when I began using it to get news from newspapers published anywhere in the world, that opened my eyes to begin thinking about the new Internet newspaper."

His interest and years of research have resulted in *Internet Newspapers: The Making of a Mainstream Medium,* published by Lawrence Erlbaum Associates. Li edited this collection of research papers and authored or co-authored several of them.



Li says the book explores whether or to what extent the standard paradigms of the traditional media apply to the Internet age, and if not, whether new ones are emerging.

It examines how online news delivery affects audiences, society, and other media. It looks at how consumers of Internet news make choices and interact with the new medium. And it gives tips on improving the operation and performance of Internet newspapers to better serve the public and to gain a competitive edge.

Other chapters delve into topics such as how web page design affects the ease of information retrieval; the effect of Internet newspapers on print newspaper circulations; and the contribution of Internet news to democracy.

With many newspapers reporting declining circulation, will print newspapers survive?

It's difficult to make predictions about media, Li says, but the Internet has changed the landscape of media competition and younger generations are already used to getting their information online.

Over time, he thinks, "the Internet will dominate. I seldom read a print newspaper unless I'm traveling, and I don't really miss it."

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—Tim Crosby

MEETING THE PRESS

Journalists asking pointed questions of government officials is a common occurrence in the United States, where a free press is considered crucial to democracy. A group of SIUC journalists is helping export this brand of journalism to countries where the news media only recently gained the freedom to question their leaders.

The group, led by associate professor Jyotika Ramaprasad, visited the east African countries of Uganda, Ethiopia, and Kenya this past July to hold workshops for journalists, journalism teachers, government officials, and leaders of social welfare groups. The aim was to foster cooperation among these parties as their countries struggle for open governments and more-democratic societies.

The trip last summer was the second in a series of planned exchanges funded by a three-year, $240,300 grant from the U.S. State Department.

"Prior to the 1990s, all three of these countries' media were controlled by one-party states or some other significant government control," says associate journalism professor James Kelly, a member of the SIUC team.

The senior journalists they met with in Africa often had, at great personal risk, agitated for more openness in government. With more freedom won, the reporters wanted training in the operation of an independent media.

▲ Kenyan journalism lecturer Isaiah Cherutich at one of the SIUC workshops. ***Photo provided.***

With the journalists, the SIUC team focused on basic reporting techniques, such as getting multiple sources—including nongovernmental sources—for their stories. Government press officers learned more about the operation of a free media and how their relationship with such might work, while social welfare groups, such as those focused on HIV/AIDS prevention, learned how to work with media to publicize important information.

There's a long way to go. Ironically, the workshop in Ethiopia had to be canceled due to recent anti-media actions by the government there. But team members were still able to meet with journalists and educators at Addis Ababa University.

More info: Dr. Jyotika Ramaprasad, School of Journalism, jyotika@siu.edu.

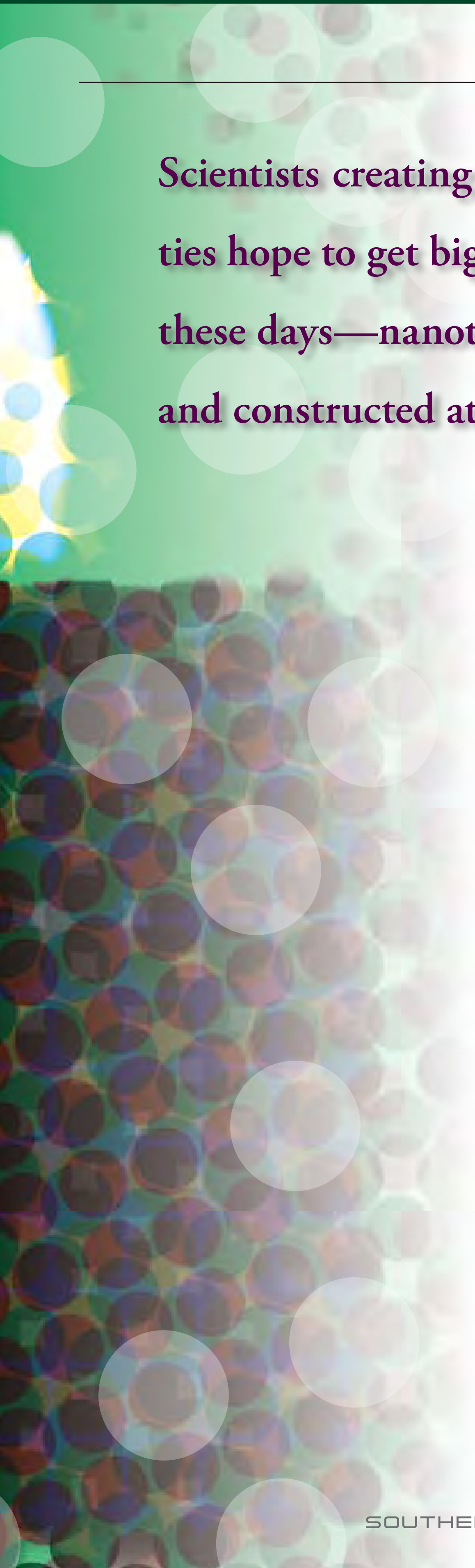
—Tim Crosby

MAKING IT NEW

A Nanotechnology Research Sampler

by Marilyn Davis

Lasers are employed in improving nuclear magnetic resonance techniques for understanding the structure and behavior of nanomaterials.
Photo illustration by Jay Bruce.



Scientists creating new materials with newsworthy properties hope to get big results by focusing small. The buzzword these days—nanotechnology—concerns materials designed and constructed at an almost unimaginably small scale.

"*Nanos* means 'dwarf' in Greek," explains Punit Kohli, an assistant professor of chemistry. "A nanomaterial has at least one dimension that measures between 1 and 100 nanometers."

How small is that? Ten atoms lined up side by side measure about 1 nanometer. A red blood cell, which can be seen only under a microscope, is thousands of nanometers in diameter.

A grain of pollen invisible to the naked eye is thousands of times bigger than the typical nanoparticle. And a veritable metropolis of nanoparticles could dance on the head of a pin, which is about 1 million nanometers in diameter.

Materials at the nano scale are hot right now—and promise to be for the long term—because their properties are so cool. A nanomaterial can behave very differently—electrically, magnetically, chemically, optically—from the same material in bulk, at the everyday sizes engineers are used to working with. And those properties can be "tuned" by making minute variations in the size of the nanomaterial. For example, a particle 2 nanometers in size might behave differently from a particle of the same substance that's 20 nanometers in size.

A GRAIN OF POLLEN INVISIBLE TO THE NAKED EYE IS THOUSANDS OF TIMES BIGGER THAN THE TYPICAL NANOPARTICLE.

This variability gives engineers tremendous opportunities to tailor and miniaturize materials and to create new types of materials and devices. It also gives them tremendous challenges in making nanomaterials uniform, reliable, and appropriate for a particular application.

Industry has already started to employ nanomaterials in products, and their possible uses include computing, electronics, medicine, and fuel storage, to name just a few. It should be noted that in many cases the issue of safety needs to be explored and resolved, and the federal government is funding work in this area.

Meanwhile, basic research in nanomaterials has seen explosive growth over the past few years. Ideas are sprouting like mushrooms after a rain. Although not all of these ideas will pan out in the end, every attempt tells scientists something more about working on the nanoscale.

STRANGE MENAGERIE

Punit Kohli is making a variety of nanoscale structures for a variety of possible uses. They're exotic-sounding beasts: quantum dots, nano-liposomes, and nanotubes, to name a few.

Nanotubes, a key focus of many materials scientists, are hollow structures that look like tiny drinking straws. In the past, *Perspectives* has featured research by SIUC's Physics Department on carbon nanotubes, which can bind and store gases such as hydrogen. But nanotubes can be made of "almost any material," Kohli says, from silica to gold to proteins—even DNA.

To make nanotubes and similar solid structures called nanowires, Kohli's lab first "grows" a thin film of aluminum oxide to use as a template. Due to the way this material naturally organizes itself, it's full of uniform, parallel nanopores running vertically through the film. One square centimeter of such a film contains a staggering number of such pores—about 100 billion.

Next the researchers deposit a chemical substance—for example, gold molecules—on the sides of the pores. Finally, they dissolve the template, leaving behind billions of hollow gold nanotubes. Alternatively, the researchers can make solid nanowires by simply filling up the pores with chemicals.

Such tubes and wires "have applications everywhere," Kohli says—in electronics, information storage, sensors, medicine. He's heard that one company is even exploring the idea of tagging valuable merchandise with customized nanorods to foil counterfeiters. (Nanotubes and nanorods can be made long enough to be seen under a microscope; their absence would show that the product wasn't genuine.)

Kohli is focusing on making nanotubes that have "different geometries—more complex sizes and shapes," he says. His lab is among the first to make curved nanotubes, branching nanotubes, and nanotubes with right-angle bends. These tubes could be used, for example, to carry current in nanoelectronic devices.

"If you want to make a device with hundreds of thousands of nanotransistors, it's really hard to connect a complicated circuit with straight structures," Kohli says. It's much more efficient to have nanotubes geometrically tailored to your fabrication needs. Likewise, in chemical synthesis, branched nanotubes might be used to channel and combine different substances in precise ways.

Connecting the dots

Kohli's lab also is working with quantum dots: semiconductor nanoparticles that, when excited by light, are fluorescent.

◀ Shelton Matthews (left), a visiting undergraduate from Grambling State University, and chemistry professor Punit Kohli go over some data relating to artificial liposomes—nanostructures they're making for targeted drug delivery.

Quantum dots emit various colors depending on their size. For example, a particle 2 nanometers in diameter might glow green, while a 5-nanometer particle of the same material might glow orange.

Kohli and other scientists think that solutions containing quantum dots could replace fluorescent dyes, which are widely used for detecting substances at low concentrations. For example, says Kohli, "Biomedical researchers tag proteins and antibodies with fluorescent dyes so they can see where they're going" in tissue cultures or in the body. Fluorescent dyes aren't very stable, however, and each type of dye requires a different wavelength of laser light to trigger its light-emitting properties.

In contrast, says Kohli, quantum dots, regardless of their size or the color they emit, can all be triggered by a single light source. Plus, because quantum dots are more photo-stable than fluorescent dyes, they would have a longer useful life. These qualities open the door to developing more efficient, less expensive detection systems.

Much work remains to be done to make the use of quantum dots practicable in real life. For example, because they are made of heavy metals, they'd have to be coated for safety for any medical use that required putting them into the body. Joe Weaver, an undergraduate assistant in Kohli's lab, is working with him on this aspect of the research.

Artificial cells

Kohli is working to make improved biosensors by incorporating quantum dots into nano-sized sacs called liposomes. These structures are like hollow artificial cells, but much smaller and with a stronger membrane.

Kohli attaches various kinds of receptor molecules to the surface of the liposomes. Each receptor molecule will dock with a particular microbe, protein, or chemical the way a key fits a lock. If that type of microbe (or protein or chemical) is present in a sample of fluid, it will hook on to the liposome with the corresponding receptor. When it does, the interaction will slightly change the color and intensity of light emitted by the quantum dots in the liposome. An instrument called a fluorometer can detect those minute changes.

Shelton Matthews, a student in SIUC's materials science REU program (see sidebar on page 14), worked with Kohli this past summer on the early stages of this concept. If the idea is successful, Kohli says, a chip with an array of these customized liposomes could test for the presence of hundreds of substances in one pass. The location where the array lit up would tell you what substance was detected. Potential uses would be in medical testing and biosecurity screening, where extreme detection sensitivity is critical.

Another of Kohli's ideas for the liposomes is to use them to carry drug molecules or genes into targeted body tissues. The liposome membrane would open under certain environmental conditions, releasing its cargo. "That trigger could be temperature, it could be pH, heat, radiation," Kohli says.

If the target tissue had a different chemical environment than healthy tissue—was a little more acid, say—the trigger would be internal. In other cases, the trigger could be X rays or ultrasound focused on the diseased tissue.

Although much work remains to be done to test the liposomes' feasibility and biocompatibility, Kohli thinks they would have certain advantages over targeted drug delivery devices now in use.

▲ Above and below: Solutions of nanoparticles called quantum dots will fluoresce at different wavelengths depending on the size of the particles. ◀ Opposite, top: Gold nanowires created in the pores of a polycarbonate template that has been partially etched away. ***Photo above courtesy Punit Kohli. Photo left reprinted with permission from*** **Nano Letters** ***2003,*** **3,** ***817, © 2003 American Chemical Society.***

SLIPPING AND SLIDING

Kohli also is working with SIUC physicist Samir Aouadi on protective thin films made of nanocomposites. From CDs to the anti-scratch treatments on eyeglasses, thin films are used for all sorts of products that require protective or etched coatings. Despite the fact that these films are only about one-twentieth as thick as a sheet of paper—if that—they can be incredibly tough.

Aouadi (pronounced oo-WAH-dee) specializes in designing thin films for wear resistance. His aim is to improve their performance in extreme conditions, such as high temperatures in air or space environments.

To do that, he's creating films with built-in solid (dry) lubricants to combat friction.

These films are called nanocomposites because they incorporate two or more substances in the form of nanocrystals. Although the idea of self-lubricating nanocomposite films was not original with Aouadi, he is the first to experiment with certain mixes of materials. And he and Kohli are trying a novel way of making them.

Solid trumps liquid

In recent years the Air Force and NASA pioneered the concept of self-lubricating nanoscale and bulk materials using solid lubricants. Why? A big issue in the aerospace industry is that solid lubricants reduce weight and simplify lubrication compared to liquid lubricants such as oil and grease. They can work at high temperatures that would vaporize or oxidize liquid lubricants, and, unlike liquids, they'll stay put in a vacuum. Plus, they're often less expensive to use.

The manufacturing and machining industries could gain productivity with nanocomposite films containing solid lubricants, Aouadi says.

PROTECTIVE THIN FILMS

Callie Bradley, a visiting undergraduate from Taylor University, and SIUC physics professor Samir Aouadi prepare to create a nanocomposite thin-film sample in a vacuum chamber. Below: Plasma in the interior of the chamber.

SIUC, NSF, and REU

SIUC's focus on materials science, and our commitment to undergraduate research, were recently recognized by the National Science Foundation with a $228,000 grant to conduct a Research Experiences for Undergraduates program in materials science.

For three summers, SIUC will bring to campus chemistry, physics, and engineering students—from universities where there is little opportunity to do research, and from groups traditionally underrepresented in these fields—for a 10-week laboratory program in materials research. Faculty in chemistry, physics, and engineering are serving as mentors.

Chemists Dan Dyer, whose research was featured in this magazine in Fall 2001, and Boyd Goodson, whose research is featured in this article, are co-leaders of the effort. The students on campus this past summer worked on a range of nanotechnology projects, including several highlighted in this article.

The hope? To recruit a new group of budding materials scientists for graduate studies in this burgeoning field.

"Tens of billions of dollars are lost every year in industry to wear of parts and related breakdowns, especially with the increase in high-speed machining," he says. He believes that self-lubricating thin films could increase the lifespan of parts like tools and bearings five- to tenfold. In addition, he says, many of the liquid lubricants used in manufacturing pose health hazards to workers and are costly to dispose of; solid lubricants would help with environmental compliance.

Solid lubricants aren't new; graphite is an example of one. But advanced lubricating materials are needed for long-term use in harsh environments or fluctuating conditions.

Aouadi's first venture into self-lubricating nanocomposites involved biocompatible thin films to extend the lifespan of hip implants (see "Smooth Sailing" at www.siu.edu/~perspect/06_sp/implants.html). In these coatings, grains of silver only about 20 to 80 atoms across are embedded in a hard substance called zirconium nitride (nitrides are salt-containing nitrogen compounds that have both ceramic and metallic qualities).

Aouadi's reason for using the silver here was actually to improve the mechanical properties of the coating. "Adding a little bit of silver limits the growth of the zirconium nitride grains," he explains. "It makes it much easier to make the grains nano-sized, which is what we want." Smaller grain size increases the film's hardness and elasticity—the key properties, besides lubrication, that are needed for wear resistance.

Knowing that the Air Force was trying to make self-lubricating oxides (tough ceramic materials), Aouadi began looking at his films' lubrication properties too. With temperature and load, he found, atoms from the silver nanograins migrate to the surface of the nitride film, forming little islands. And because silver is a soft metal that shears easily—that is, it will deform and slide under force—the islands act as lubricants.

Aouadi and his students make the nitride films by a technique called sputtering, commonly used to manufacture optical coatings, semiconductors for integrated circuits, and other products. In a vacuum chamber, plasma is used to drive atoms off of solid source materials, such as silver and zirconium. Those freed atoms then deposit onto a substrate.

In manufacturing, the substrate would be a product. In Aouadi's lab, it's usually a chip of stainless steel. The deposition is controlled using various techniques; Aouadi currently has

a $42,000 grant from Research Corporation to analyze and better control this process.

A long journey

Aouadi's lab team wear-tests the films with a machine that spins the coated metal chip against an aluminum oxide pin. After a "travel" distance of about six miles, they measure the depth of the wear track and compare the performance of different coatings.

"We're trying for a low friction coefficient—low resistance to motion—in the environment that the film is designed to be used in," Aouadi says. Some of the testing is done under normal atmospheric conditions; some is done in nitrogen or argon to simulate space conditions, where oxygen and water vapor are absent. Aouadi's lab will soon be testing films in high temperatures as well.

They have found that the nanocomposite nitrides are much more wear-resistant than conventional nitrides. "The question is at what point you lose some of the integrity of the film," Aouadi says. Here's the rub: Enough atoms of the lubricant must migrate to the surface of the film to reduce friction substantially. But if too many atoms move to the surface, that could affect the integrity of the material in the long term.

In collaboration with scientists at Argonne National Laboratory, Aouadi has been working with other metals and metal compounds as lubricants because silver is "too mobile" for some applications. He is experimenting with other nitrides as well. Fellow SIUC physics professor Mesfin Tsige is doing some of the computer modeling of these compounds.

"The challenge of nanocomposite design is controlling the self-lubrication process and the mechanical properties," Aouadi says. "You know the properties of the nitride or oxide, and you know the properties of the metal, but when you mix them, no one can simulate what properties you're going to get. There's a lot of trial and error in the design process, and even then you can't always get the properties you want."

To get around that problem, Aouadi and Punit Kohli are creating films where the solid lubricant is included as tiny inserts in the film, not as part of the film's chemical structure. They're beginning with the same kind of films Kohli uses to create nanotubes: aluminum oxide films with nano-sized pores. In this case, they're attempting to fill the pores with silver or other lubricating compounds.

Whether the pores are filled or empty, the thin film will be equally hard and elastic, Aouadi explains. In other words, the researchers can control the properties of the film and the lubricant independently. And since the nanopores are open to the surface of the film, he says, "the lubrication should be far better."

He, Kohli, and their students are the first to try this method for making self-lubricating nanocomposite films. If it works, they plan to try combinations of other types of oxides and metals.

Shell game

Ultimately they want to create the metal inserts in nitride films, which are often tougher than oxide films. But nitride films can't be created with nanopores, so the scientists will try a neat substitution trick. After filling the pores of an oxide with metal, they'll dissolve the oxide. That will leave the metal inserts as skinny rods sticking up from the underlying substrate like bristles on a brush. Then they'll attempt to deposit nitride material around the rods.

"The deposition part is going to be challenging," Aouadi admits. Whether it will work at all is an open question, but SIUC has filed a provisional patent application on

Doctoral student Prakash Basnyat uses an ellipsometer to look at some of the properties of a nanocomposite thin film. Above: A wear-testing machine puts a film-coated chip through a trial.

the concept. If nanocomposite nitride films can be made this way, the manufacturing cost would be much less than with the sputtering method.

The Air Force is interested in both ways of making the self-lubricating thin films, and Aouadi has begun sending them samples to test. Since different solid lubricants work well under different conditions—for example, silver works only up to 600°C; molybdenum disulfide works well in space but not in humid conditions—an eventual goal for both the Air Force and NASA is to include more than one type of solid lubricant in the same film, to cover different environmental situations.

That would make it easier for the space shuttle, for example, to weather both extreme heat and cold, both Earth's atmosphere and the vacuum of space.

FILTERING ELECTRONS

A new generation of electronic devices is the goal of other thin-film research at SIUC.

Imagine a computer that doesn't need to "boot up" when you turn it on. It's ready to use as soon as you flip the switch and has a memory system that doesn't require a constant source of power and would remain intact even if you turned it off without saving your work.

Shane Stadler, an assistant professor of physics, is working on thin films made of materials called "half-metallic alloys." These films could make possible a magnetic random access memory that is more stable than the RAM currently used in computers. They also could make possible many other advances in electronics, such as a whole new generation of sensors, and transistors that require less energy to operate.

This field of product design is dubbed "spintronics." The term derives its name from a physical property electrons possess called "spin," which occurs in one of two states: "spin up" or "spin down."

Stadler and other scientists are trying to harness this inherent subatomic difference. Where a normal electrical conductor, such as a copper wire, allows the flow of both kinds of electrons, thin films made of half-metallic alloys filter the current so that only spin-up electrons or spin-down electrons can flow through.

"That [filtering] gives you more properties to exploit in developing a new class of electronics that will be more intricate and more versatile," Stadler explains.

Aiming for perfection

Crude spintronics devices are already being used in things like read heads for hard drives, Stadler says, "but the materials are

◀ Shane Stadler with the vacuum chamber he uses to make thin films that can "filter" certain kinds of electrons. Above, he uses tweezers to hold a cobalt-magnesium-silicon thin film created from the source alloy shown next to it.

nowhere near perfect. The devices they're shooting for—magnetic RAM is the Holy Grail—require near-perfect half-metallic materials."

In theory, half-metallic alloy films are 100-percent efficient at filtering spin-up electrons from spin-down electrons. In practice, things are not yet that tidy.

"When you make the films, the atoms don't always go to the proper position—they're disordered," Stadler explains. "That's one of the major problems that need to be overcome."

The films, which are only about 100 atoms thick, are made via a technique called pulsed-laser deposition. A fingernail-sized chunk of the alloy—a mix of cobalt, manganese, and silicon—is put into a vacuum chamber along with a heated substrate (usually a silicon chip). Pulses of ultraviolet laser light fired at the alloy vaporize a plume of atoms from its surface. Some of those atoms collect on the substrate, where they form bonds with it and with each other and grow into a thin film.

Much of Stadler's research involves finding the best "recipe" to prevent imperfections in the films' composition. To do that, he experiments with variables such as changing the temperature, applying a magnetic field, and changing the atomic structure of the substrate (which can affect the atomic structure of the film). Another major experimental aim, he says, is to alter the properties of the thin films by "substituting in a few atoms for one of the materials, like aluminum for silicon."

SPIN DOCTOR

The property called spin is also essential to an existing technology: nuclear magnetic resonance. NMR is a powerful tool for exploring worlds hidden from view. That includes the nanoscale world, where scientists designing new materials need to understand the behavior of atoms and molecules.

Some of us have benefited directly from one NMR technology: MRI, which images soft tissue without the use of X rays. Other types of NMR allow scientists to study substances at the sub-microscopic level.

For instance, chemists making new types of substances rely heavily on NMR to monitor their progress. They know how much of each element they've put into a sample. But did they succeed in making what they hoped to make?

"The chemical formula isn't good enough," says chemistry professor Boyd Goodson, who's working to improve NMR techniques for both medicine and materials science.

"You need to know how the molecule is laid out—its structure. That's really what determines what the molecule is."

NMR relies on the fact that the nuclei of many atoms act like tiny bar magnets—that is, have spin—when exposed to a strong magnetic field. A liquid carrying a particular chemical in solution is exposed to a super-strong magnet. The resulting spins of the nuclei will align either with or against the magnetic field—either "spin up" or "spin down."

Then radio waves are pulsed through the sample, pushing the magnetic spins away from equilibrium a bit—the quantum-mechanical equivalent of a wobble. Once disturbed by the radio waves, many of the nuclei will wobble in sync, at a specific frequency. (This is the "resonance" part of NMR.) The NMR equipment picks up and amplifies those signals, and a computer generates a characteristic spectrum for the substance.

The more that molecules in a sample interact with each other, the more informative the NMR signal can be. When molecules affect each other's nuclear spins—"talk to each other," as Goodson says—the resulting frequency variations help scientists determine the number and kinds of atoms in the molecules and how they're connected. And "spin relaxation"—the way the magnetic spins return to equilibrium after being exposed to the radio waves—not only reveals information about molecular structure, but also can be used to deduce how parts of molecules move and interact.

The simplest NMR spectrum resembles a horizontal line with sharp peaks at various places. Each peak is a unique signature for a given type of atom in a particular chemical environment. But most NMR techniques are much more complicated, enabling chemists to model complex molecules like proteins in 3-D and even to study solid-state materials.

Improving NMR means, in many cases, trying to get more information from a smaller sample of material. NMR requires samples containing trillions upon trillions of molecules—at least a fraction of a milliliter of liquid. That may sound tiny, but providing that much of a purified sample can be a big hurdle for a chemist trying to synthesize a new drug or material at the nanoscale.

Why is so much sample needed? The ratio of up spins to down spins in a given sample is virtually 50:50, and the NMR signals from those spins cancel each other out. Useful signals can be obtained only from the handful of spins that shift the overall balance slightly to up or slightly to down. "Only one in 100,000 [nuclei] gives you any information," Goodson says.

He's trying to shift the ratio by using lasers to force samples into having a greater number of spins aligned the same direction, whether up or down. (Another way of putting it is that these samples will be more highly magnetized.) His aim is to increase the spin difference so that at least one in 10 nuclei will give workable information. Much more data could then be gathered from a much smaller amount of sample.

▲ Boyd Goodson is developing new NMR techniques to give more useful information to materials scientists and medical researchers.

This trick only works with certain substances. Goodson is experimenting extensively with xenon, a gas. Through a multistep process, laser light can be used to boost the spin alignment of xenon nuclei. This produces highly magnetized xenon that gives a very strong NMR signal.

Xenon is chemically inert, so it won't change substances it comes in contact with. And because it "likes to go into stuff," as Goodson says, it can act as a probe to find things out about a material indirectly. It can be used to "map" a molecule's surface, or the cavities of a porous material, or the shape of a protein.

ENZYME PRESERVATIVE

Not Quite Nano, But Good to the Last Drop

Biomolecules have become almost ubiquitous in laundry and personal care products. Detergents usually contain enzymes to help digest stains, and shampoos and conditioners often use proteins to add shine and thickness to hair. Now, researchers have developed a way to carry these biomolecules in microscopic beads that could help get your clothes cleaner by releasing the biomolecules at the appropriate time in the wash cycle. The beads could also extend the shelf life of countless consumer products.

SIUC chemistry professor Bakul Dave, former postdoctoral fellow Kiranmayi Deshpande, and two colleagues at Genencor International in Palo Alto, Calif., used beads of silica gel (also called sol-gels) to encapsulate biomolecules, such as enzymes called alkaline proteases, commonly used in detergents to help remove stains from dirty clothes.

The gel beads swell and contract depending on the ambient chemical conditions. In detergent, the beads are tightly compacted, sealing in the biomolecules. When the detergent is mixed with water, however, they will expand and release their cargo.

In short, the fragile enzymes, which can stop working after being exposed to heat, air, and light for too long on the shelf, are protected within the beads until they are needed in the washing machine. This means the product will continue to work as well as the manufacturer intended until the very last drop is poured from the bottle.

The team tested the gels as an additive to two different detergents: a generic detergent ingredient (sodium dodecyl sulfate) and a commercial laundry product whose enzyme content had been destroyed by heating. They also tested the shelf-life of the gels in detergent and found that very little enzyme leached out of the beads during storage—only about 1 percent after one month.

A patent is pending on the SIUC technology.

This article was adapted from a press release by the journal ***Advanced Materials****, where Dave and his colleagues published their results. Used by permission. The research was funded by a grant from Genencor. For more info: Dr. Bakul Dave, Dept. of Chemistry and Biochemistry, dave@chem.siu.edu.*

Amber Hurley, an REU student from Alice Lloyd College in Kentucky, with some of the silica gels she worked on in Bakul Dave's lab for controlled release of substances. These gels are similar in concept to the detergent beads described above. In this case, they will hold a dye until a change in local pH causes the gels to swell and release the dye. ***Photo by Bakul Dave.***

Getting a boost

In some cases you can also use highly magnetized xenon to boost the spin alignment of the molecules you want to study, yielding a stronger NMR signal from a smaller sample. That would allow scientists to analyze the target material directly.

This boosting process is slow and inefficient, however. To improve it, Goodson is enlisting liquid crystals.

Molecules in a normal liquid tumble around freely and influence each other's spins only slightly. As Goodson says, "They're not talking to each other very much." This results in an easy-to-interpret NMR spectrum, but one that doesn't always give much information about molecular structure.

Molecules in a solid, because they're locked into place, influence each other's spins a lot. But this volume of molecular "talk" can be too much of a good thing for NMR. Like voices in a crowd that blur into gibberish, the result is an NMR spectrum with broad, messy, unintelligible peaks.

NMR scientists need something in between, and liquid crystals fit the bill.

Molecules in a liquid crystal still flow, but they also have some order—some net alignment. If you take molecules of the material you want to study and put them inside a liquid crystal, their movement is cramped a bit by the liquid crystal matrix. As a result, the spins of their nuclei have a greater opportunity to influence each other.

Liquid crystals have been used in NMR for decades to yield greater information about molecular makeup. But Goodson's lab is one of only a handful trying to use them to study substances called inclusion complexes, which are created when larger "host" molecules bind or encapsulate smaller "guest" molecules. "These complexes are interesting for drug delivery applications, and you can use them to model protein interactions," Goodson says.

Unfortunately, the host and guest molecules interact weakly, and their NMR signals may not give much useful information about their interactions. "We'd like to enhance the NMR signatures of those interactions by using liquid crystal matrices as a way to get spins to talk to each other that wouldn't talk otherwise," says Goodson. That would tell scientists more about the way these molecular complexes look and work.

Goodson also wants to add his souped-up xenon to the mix to boost NMR signals from these complexes or other molecules of interest. The idea is that the liquid crystal matrix will force the xenon and the target molecules to interact more than they would in a normal liquid. And that should enable xenon to boost the magnetization of the target molecules more efficiently and powerfully.

"Ultimately we want to use this to study proteins," says Goodson. Determining the structure and movement of these big, intricately folded molecules is key to understanding the role they play in the body—and understanding how disease is caused by proteins that go awry.

Better MRI

Another biomedical application that Goodson is working on is improving MRI technology. This research project is led by fellow SIUC chemistry professor Yong Gao.

The limiting factor with MRI is contrast. "We need sharper images" to identify abnormal tissue, Goodson says, "and we want more information about the nature of the tissue."

Getting that information will require better contrast agents—substances administered to the body to allow better differentiation of tissue types in MRI images. For example, iron oxide is used as a contrast agent to image the liver and lymph nodes. Its strong magnetization dramatically changes the signal from nearby water molecules in cells, giving better contrast to the resulting MRI images. (Since the body is mostly water, MRI information comes mostly from water molecules.)

But iron oxide has a lot more to offer, think Goodson and Gao. "We and other scientists are trying to develop new kinds of iron oxide–based contrast agents that could report back information about what kind of disease a person has and how that disease is progressing," Goodson says.

"If you had an imaging [technique] that could report, 'This is not just odd tissue, it's not just cancer, it's cancer that's characterized by overexpression of a particular protein,'—that's a lot more information than you would have had otherwise. For example, it would be good to know not just where breast cancer is present, but which kind. That's an important direction that MRI is going."

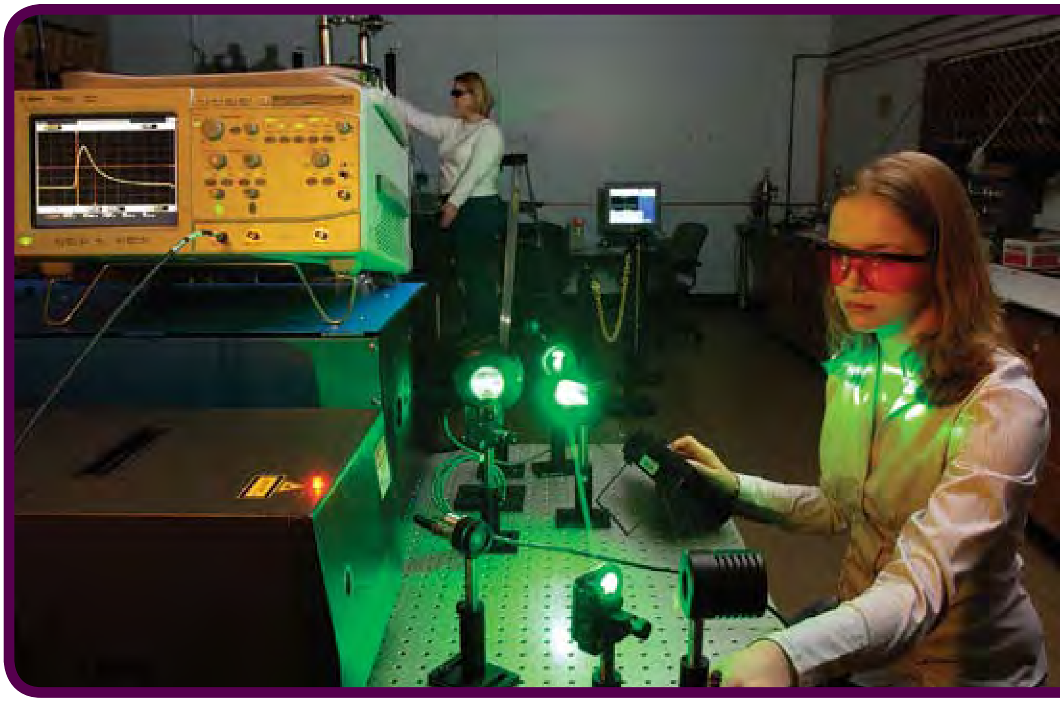
Gao's lab is making nanoparticles of iron oxide that have an extra-strong magnetic response when placed in a magnetic field. Then they're coating the iron oxide nanoparticles with branch-like molecules called dendrons. By using specific types of dendrons, they hope to enable the nanoparticles to infiltrate specific types of tissue, such as certain kinds of tumors. The result would be a localized dark spot on the MRI image.

The team also is exploring whether these nanoparticles might have different spin behavior in diseased cells than in healthy ones. For example, Goodson's lab is finding intriguing hints that the particles affect the spin relaxation rate of the surrounding water molecules in a way that varies with pH levels.

"It turns out that cancer cells may often have a slightly lower pH than noncancerous cells," Goodson says, warning, "It's a small effect, it isn't all cancer cells, and the research is very preliminary. But this shows that maybe you can make a contrast agent that need not be specific to a particular kind of tissue. Maybe it goes into a number of different body tissues, but because it changes spin relaxation in a way that's selective to the local environment, it reports back differently [from diseased tissue]."

Goodson's NMR experiments with the nanoparticles give Gao the feedback he needs to try new design ideas. And the group is now taking the first tentative steps toward eventual experiments in lab animals. Gao, Goodson, and SIUC physiologist Jodi Huggenvik have begun studying the uptake of these nanoparticles by cancer cells in solution and subsequent changes in the particles' spin behavior.

Caitlin Newberry works with a laser used to produce highly magnetized xenon for use in the NMR equipment being adjusted by Kathleen Chaffee (background). SIUC undergraduates when this photo was taken, both have gone on to graduate studies in chemistry, Chaffee with Boyd Goodson.

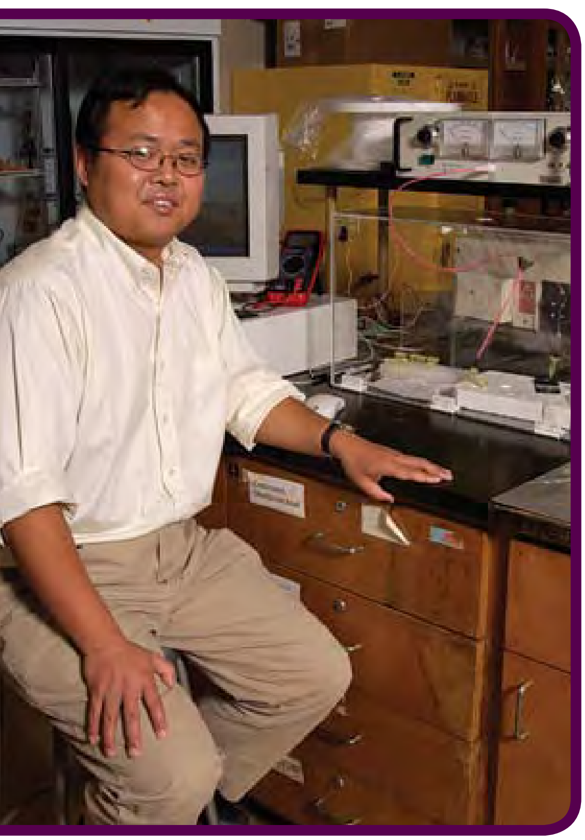


DRIVING CHANGES

Bio-imaging is only one possible application of these iron oxide nanoparticles, Gao says. They can also be employed as a cheaper, environmentally friendly way to trigger chemical reactions in industrial processes.

The chemical industry relies heavily on catalysis, in which compounds called catalysts are used to drive chemical changes in another substance. Gao's lab focuses on catalysis in liquid organic mixes, which are precursors to drugs, fuels, and other products.

Anchoring catalysts to resin-based "scaffolds" allows the catalysts to be recovered from the liquid after they've done their job and to be reused in a new batch of liquid. Such recycling is an important cost saver in process chemistry, which involves making large quantities of substances. "One way to cut the costs of drugs is repeated use of catalysts," Gao notes. And recycling avoids waste that contributes to pollution.



But many catalytic reactions are very slow, or even impossible, with resin-based scaffolds. Gao says his iron oxide nanoparticles offer a better alternative.

First he coats the particles with a thin polymer shell. The polymer serves as a buffer to counteract the particles' natural tendency to collide and clump together. (Clumping would hinder the catalysts from doing their job.) Then he attaches catalysts to the polymer shell.

These doctored nanoparticles disperse evenly in liquid. In part because of that, and in part because of their small size, they enable much more rapid, complete, precise catalytic reactions. The end result is a purer chemical product—crucial for drugs—via a more efficient process.

After the chemical reactions are completed, the nanoparticles, with their catalyst molecules still attached, can easily be separated from the liquid with the aid of a low-field magnet. Experiments in Gao's lab have shown that they can be used over and over with no drop in catalytic effectiveness.

Forcing a reaction

Drug companies are already interested in this technology, which SIUC is patenting. But Gao is more excited about another direction of his research: producing new *types* of catalysts for organic chemistry synthesis.

Because of their incredibly small size, nanoparticles make possible catalytic reactions that would not be possible otherwise. "You can change catalytic properties once you put the catalyst on the surface of a nanoparticle," Gao says. "That is very cool. It's a very exciting new area of research."

◀ Yong Gao is using nanoparticles to improve medical imaging and to make possible new types of catalytic reactions.

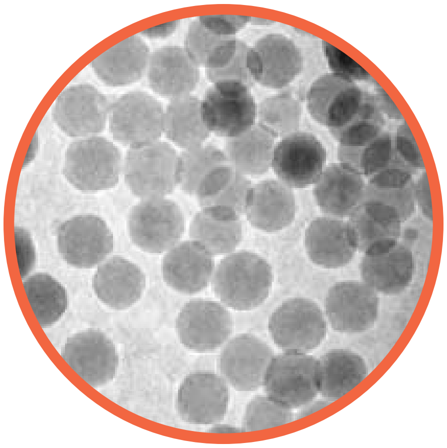
▶ Iron oxide nanoparticles as seen through an electron microscope. ***Photo by SIUC IMAGE Facility.***

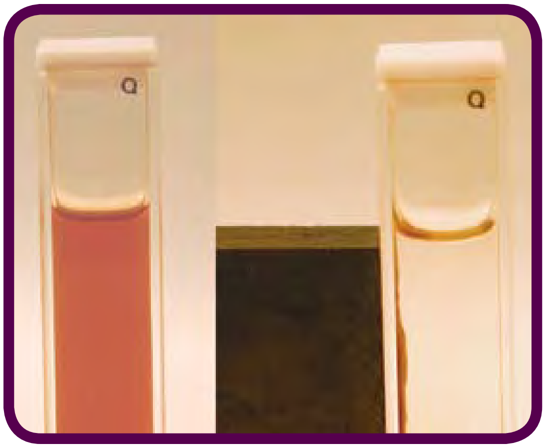
Attaching different types of chemical units to the surface of nanoparticles puts those units in such close proximity that they will interact in new ways. "Standing shoulder to shoulder forces them to act in collaboration with each other as catalysts," Gao explains. And they will trigger these catalytic reactions under mild conditions, meaning that extremes of temperature and pH aren't necessary.

Gao has proven the concept by attaching two kinds of amino acids to his iron oxide nanoparticles, then putting the particles in a liquid contaminated with a pesticide called paraoxon. Free-floating in such a liquid, these two acids trigger no changes in the paraoxon. But anchored side by side on the particles, they act together as a catalyst. They break the bonds of the paraoxon molecules, neutralizing them by chopping them into pieces.

Paraoxon, which is very similar to chemical warfare agents such as sarin, belongs to a broad class of compounds called organophosphates, many of which are pollutants of great concern. Gao's finding, published by the journal *Organic Letters,* suggests the possibility of new technology for cleaning up contaminated agricultural and military sites.

Using nanocatalysis to break chemical bonds might have many applications beyond pollution control. Gao is already collaborating with several groups on possible





Iron oxide nanoparticles dispersed (left) in a solution can be separated out (right) with the aid of an external magnet. *Photo courtesy Yong Gao.*

medical therapies, and also is exploring possibilities for cheaper fuel production.

"That's the excitement of research," he says, "expanding into different directions with one material, solving problems, bringing the costs of industrial processes down."

Samir Aouadi's work has received funding from Research Corporation, a private foundation dedicated to the hard sciences. Punit Kohli recently won a Nanoscale Exploratory Research grant from the National Science Foundation to develop a novel method of using nanostructures to deposit protein molecules on a surface. Boyd Goodson's NMR research is being funded by a $550,000 CAREER award from the NSF and by a $100,000 Cottrell Scholar grant from Research Corporation. The NSF also awarded Yong Gao a $469,500 CAREER award and Shane Stadler a $480,000 CAREER award for their research.

Many of the faculty in this article have had additional support from other external agencies and have had seed funding from SIUC's Materials Technology Center and Center for Advanced Friction Studies.

Contact information: Dr. Samir Aouadi, saouadi@physics.siu.edu; Dr. Yong Gao, ygao@chem.siu.edu; Dr. Boyd Goodson, bgoodson@chem.siu.edu; Dr. Punit Kohli, kohlip@siu.edu; Dr. Shane Stadler, sstadler@physics.siu.edu.

Additional nanotechnology research projects are underway at SIUC; look for more coverage in future issues of ***Perspectives****.*

Tim Crosby contributed to this article.

Over the past few years *Perspectives* has featured a number of other materials science projects at SIUC. Potential applications include uses in transportation, construction, mining and manufacturing, energy, electronics, and medicine. Faculty and staff in the departments of chemistry, civil engineering, mechanical engineering, physics, and surgery have spearheaded this research. Here's where to learn more.

Improving carbon-composite automotive brake linings and rotors
www.siu.edu/~perspect/04_fall/brakes.html

Using ceramic nanocrystals to protect carbon composites from oxidation
www.siu.edu/~perspect/01_sp/carbon.html

Developing coatings for improved hip implants
www.siu.edu/~perspect/06_sp/implants.html

Making organic thin films with new properties for sensors and electronics applications
www.siu.edu/~perspect/01_fall/nanotech.html

Testing new concrete mixes for deep foundations using bottom ash from coal-fired power plants
www.siu.edu/~perspect/02_sp/concrete.html

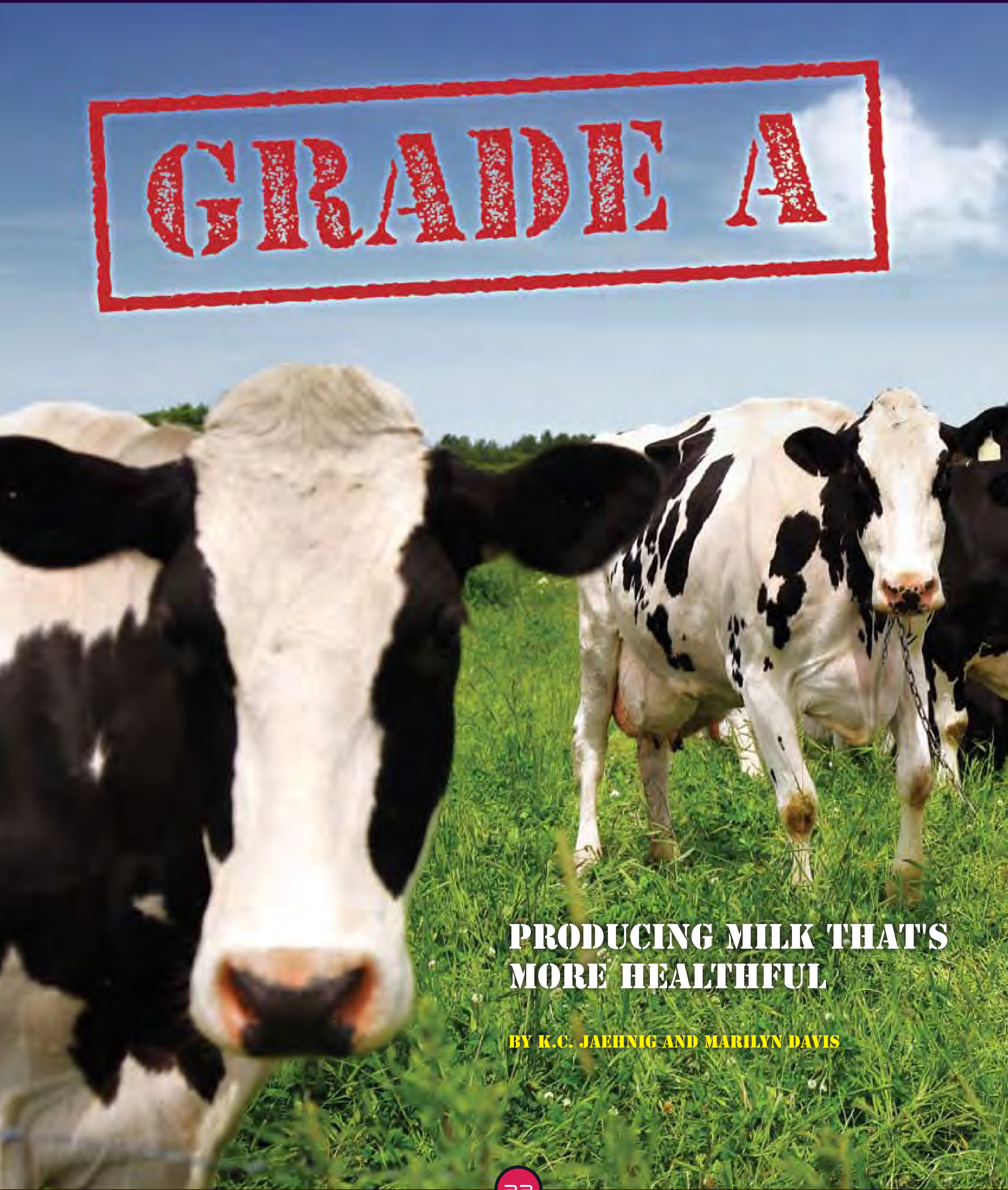
Inventing a super-wear-resistant diamond-containing composite for drilling and machining
www.siu.edu/~perspect/05_fall/diamond.html

Developing nontoxic, synthetic clay materials for ultrasound-triggered drug delivery
www.siu.edu/~perspect/04_sp/drug_delivery.html

Exploring the ability of carbon nanotubes to store and release gases such as hydrogen
www.siu.edu/~perspect/03_sp/nanotubes.html

Using specialized glass as a template to make uniform-sized metal nanoparticles
www.siu.edu/~perspect/02_fall/alchemy.html

Also see the web sites of SIUC's Center for Advanced Friction Studies (frictioncenter.siu.edu) and Materials Technology Center (mtc.engr.siu.edu/mtc).



GRADE A

PRODUCING MILK THAT'S MORE HEALTHFUL

BY K.C. JAEHNIG AND MARILYN DAVIS

Could cheese cut your cancer risk? Could ice cream increase your chances of avoiding inflammatory disease? Could milk build a better brain? And could they do these things while saving the family dairy farm?

Amer AbuGhazaleh, an SIUC animal scientist, is trying to find out, with a three-year, $125,000 grant from the Illinois Council on Food and Agricultural Research (C-FAR).

That project is geared toward boosting the amounts in milk of two types of fatty acids believed to help protect against heart disease, cancer, and diabetes, among other ailments. One type, omega-3 fatty acids, comes primarily from fish oil and flaxseed oil. The second type, conjugated linoleic acid (CLA for short), is produced by bacteria active in the rumen, the first compartment of a cow's stomach. Cows produce only small amounts of CLA, however—not enough to give their milk an extra health punch.

During his doctoral research in South Dakota, where he worked with cows in confinement operations, AbuGhazaleh increased the amount of CLA and omega-3 fatty acids in their milk three- or fourfold when he added oils rich in those acids to their diet. But he thought he could do better.

So the first dietary change he made with one group of his Holsteins at SIUC was to turn the cows out to pasture rather than keeping them in the barn.

"Grazing has been shown to increase the concentration of [CLA] fourfold—we don't know why," he says.

He also began feeding those cows a mix of corn, soybean meal, vitamins, and minerals laced with a little fish oil and linseed oil.

"Not only does the linseed oil have omega-3 fatty acids, but it also acts as a precursor for the CLA, providing [material for the stomach bacteria to go to work on]," he says.

Combining the special feed with grazing caused CLA levels to increase a whopping tenfold and omega-3 fatty acids to increase fivefold compared with milk from cows not given the special diet, AbuGhazaleh found.

The dietary changes also cut the milk's saturated fat content in half—almost down to the content typical of 2-percent milk. "We're producing 2.5-percent milk right from the cow," he says with a grin.

He notes that enriched dairy products wouldn't be expected to be someone's only source of CLA and omega-3 fatty acids. But, he says, "If you replaced your 12-ounce can of Pepsi with the same amount of milk from our grazing study, you would get 278 milligrams of CLA and 135 milligrams of omega-3."

That could be a significant help to consumers trying to get the daily 650 milligrams of omega-3 fatty acids currently recommended by the National Institutes of Health. That amount equates to about three or four servings of fatty fish per week, AbuGhazaleh says.

While many small dairy farms already have turned to grazing as a cost-cutting measure, they are finding that even lower feed costs don't offset low prices for raw milk. AbuGhazaleh acknowledges that the special feed mix would be a little more expensive for farmers than the feed they typically use. But, he says, "our goal is to create a niche market" with increased revenues that would more than compensate for the extra cost. Many consumers are willing to pay a premium for omega-3 enriched eggs, he notes, and he expects that many would likewise pay a premium for enriched dairy products.

In fact, that's just what he found from a consumer survey conducted on campus earlier this year, where more than two-thirds of respondents said they'd be willing to pay between 10 and 20 percent more for enriched dairy products.

Most of that income could stay on the farm if farmers took advantage of newly available processing equipment, downsized to fit the needs of the smaller producer, to make cheese, ice cream, and pasteurized milk right at the dairy. To show it could be done, AbuGhazaleh spent a little less than $500 on equipment that allowed him to churn out those products in his lab.

He and his team made both enriched and nonenriched samples of these products, then served them up in a blind taste test to about 200 students and faculty. At least 60 percent said they liked the enriched products. (The figure is actually skewed to the low side, since some of the testers didn't care for dairy products in general but succumbed to the inducement of coupons for participating in the taste test.)

◀ **Through simple dietary changes, dairy specialist Amer AbuGhazaleh has been able to greatly increase the levels of certain healthful fatty acids in milk.**

▶ **Fermenters allow AbuGhazaleh to study how CLA, one of those fatty acids, is produced in the cow's stomach.** ***Photo by Amer AbuGhazaleh.***

©iStockphoto.com/Lisa Gagne

Amer AbuGhazaleh at the SIUC Dairy Center.

A team of undergraduate and graduate students conducted the taste-testing study of enriched and nonenriched dairy products. From left: William Brown, Gwenetta Flowers, Jaclyn Hollander, Justin Garleb, Deidra Felton, and JoAnn Morgando.

In addition to their herd of Holsteins, AbuGhazaleh and his students work with fermenters: custom-built contraptions of glass bottles, tubing, and controls set up to mimic what happens in the cow's rumen. Each bottle has a tube that conveys food into it, a tube that transports "saliva" to it to aid its digestion, and a tube that carries waste out of it and into a white plastic bucket.

These fermenters have certain advantages over live animals when it comes to AbuGhazaleh's research. "The biggest of these is cost," he says. "A cow has a 50-gallon stomach. It can eat 60 pounds of food a day, where the fermenter uses less than a quarter of a pound."

The fermenter experiments, part of a pilot study funded by an SIUC Faculty Seed Grant, are geared to look at what factors control the production of CLA in the rumen. "There are so many interactions in the cow's stomach—it's like a big puzzle," AbuGhazaleh says.

To follow the action, he adds molecule-sized markers to the fatty acid contained in the feed used for the fermenters. A type of oleic acid, it serves as a precursor for CLA production. The markers allow AbuGhazaleh to track what happens to the oleic acid in the digestive process—how microbes break it down and form intermediate compounds to eventually produce CLA.

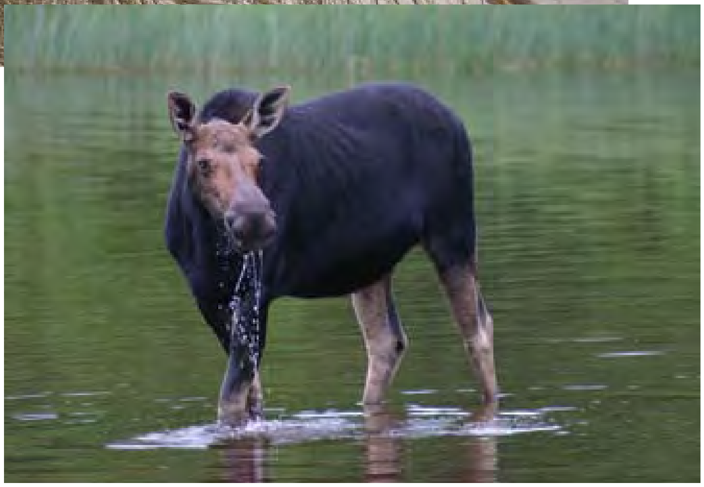
"These markers are very expensive—between $1,000 and $5,000 per gram," AbuGhazaleh says. "One gram in a cow's stomach would be so diluted it would not work as a tracer, but the fermenter has a volume of less than a liter."

Understanding the complexities of how CLA is produced by the cow may enable him to take measures to further boost CLA levels. "We can experiment with certain conditions [in the fermenter studies], such as pH, food retention time, and different oil sources [in the feed]," he says. Those studies are ongoing.

AbuGhazaleh has his sights set on more than just milk, though. Next up: He and SIUC animal science professor Gary Apgar recently were awarded C-FAR funding through the College of Agriculture to see if tinkering with pigs' diets can increase omega-3 levels in pork. Stay tuned.

For more information, contact Dr. Amer AbuGhazaleh, Dept. of Animal Science, Food and Nutrition, aabugha@siu.edu.

Preserving the Parks



▲ Indiana Dunes National Lakeshore. ▶ Isle Royale National Park.
Photos by John Burde.

"The National Park System gives people an opportunity to see places in a very natural state, and to explore and learn about different types of natural environments. The National Parks Conservation Association, a nonprofit advocacy group, asked us to assess the health of six park units around Lakes Michigan and Superior. We compiled and synthesized all the existing information from scientific studies and management plans about things like habitat, air quality, water quality, the status of wildlife and plants, and preservation of cultural structures and artifacts.

"Each site has unique challenges. For example, many have rare plant communities, and the parks are working hard on restoring and protecting those sensitive areas.

"It's important to get a snapshot of the state of the parks. How well are we doing in protecting natural resources? Which places need better protection? And what are the success stories in preserving places? There have been many."

—*Mae Davenport*

Ed.—Forestry professors Mae Davenport, John Burde, and Jim Zaczek, along with six graduate students in forestry, studied Indiana Dunes National Lakeshore, Sleeping Bear Dunes National Lakeshore, Pictured Rocks National Lakeshore, Isle Royale National Park, Apostle Islands National Lakeshore, and Keweenaw National Historic Park. The result will be comprehensive reports on each that will help the National Parks Conservation Association inform the public about the status of the parks and garner support for preservation efforts.

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