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Let's Get Small

Sarah Webb '96


LET'S GET SMALL

By Sarah Webb

Furman chemistry professors and students delve into the cutting-edge field of nanotechnology.

In the last two years, Laura Glish has spent more hours than she can count in the Plyler Hall basement. The gregarious chemistry major has not been hiding from anyone; she's been studying the topography of tiny surfaces.

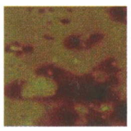
Using an atomic force microscope, she generates pictures that resemble relief maps, but of an area 1/10,000th the size of a pinhead. The whims of this sensitive and fragile instrument require patience and quiet. "I used to get in trouble my freshman year for too much talking," Glish, a senior, admits.

But her images allow her colleagues to actually see the fruits of their work, a critical component of a growing field of science that focuses on examining and designing materials smaller than most of us can even imagine.

"Nanotechnology" — the science of materials between 1 and 100 nanometers — is widely considered in science and technology circles to be one of the next great movements in research. Originally used by Eric Drexler to describe the science of tiny robots and machines, the term "nanotechnology" has broadened to include the investigation of materials just a few atoms or molecules wide, and the study of new materials that could one day give you a cell phone the size of your fingernail. (A nanometer is equal to 0.001 micrometer, 0.00000003937 of an inch, or 0.000000001 of a meter.)

Images from an atomic force microscope, clockwise from top left: Five-micron image of an additive blooming to the surface of polyethylene; two-micron image of bundles of polyethylene strands; 40-micron image of a polymer with imbedded crystals; DNA strands immobilized on mica. A micron equals one-millionth of a meter. Images courtesy Laura Wright's research group.

In projects that parallel the National Nanotechnology Initiative that provides funding for research, faculty and students at Furman have been working on new materials for electronics and on tiny silver particles that could someday serve as biosensors. But on top of that, nanotechnology research at Furman is already shedding light on such things as the metalized films on top of Pringle's cans, as well as other products that we take for granted in our daily lives.



Former and current students recognize chemistry professor Tim Hanks by his crazy Hawaiian shirts and Birkenstocks worn with socks. In scientific circles, however, Hanks has built a niche within the growing field of novel materials, an essential component of nanotechnology research. He's developing new chemical compounds to serve as the foundation for the circuits, fabrics and medical technology of the future.

Hanks talks optimistically of a future of tiny robots and minuscule computers made of fabric-like materials sewn into clothing, but his primary interest is in the materials that could move these technologies from science fiction to science fact.

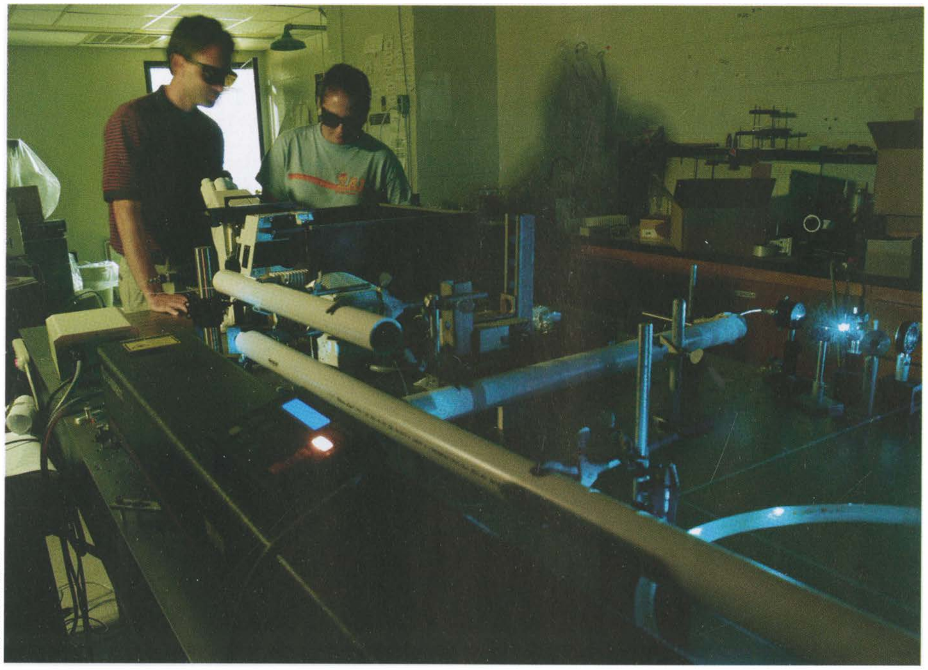
Before nanotechnology became the latest buzzword, Hanks and his students had engineered plastics that conduct electricity. These types of materials have recently become hot commodities in the engineering push toward nanodevices. Traditional silicon chips that power today's gadgets can be made only so small and in a restricted number of shapes. With efficient conducting plastics, engineers could eventually construct electronics that are both lighter and smaller than we have today.

Of critical importance to nanotech research has been the discovery that in chemistry, the whole is not necessarily equal to the sum of its parts. Scientists have found that small groupings of a few atoms do not behave in the same way as larger chunks visible to the naked eye. Instead of looking like the ring on your finger, gold nanoparticles 1/3,000th the width of a human hair are actually purple — and they have unusual chemical and electronic properties.

"The color depends on how big they are, not what they're made of," Hanks says. Because of the relative number of atoms on the surface of such small particles, they could make faster capacitors for electronics, allow chemists to synthesize molecules in new ways, or serve as biological tags for new medical applications.

Bringing together new materials for electronics and circuitry could form the basis for all kinds of imbedded

Using a microscope and laser, Caroline Ritchie and Jeff Petty view and count silver nanoclusters bound to DNA.



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nanoelectronics, such as a mini-computer, or for an implantable biochip that might monitor blood glucose in a diabetic patient. Hanks and his research team of students and postdoctoral associates have been developing ways to bring these tiny pieces of gold nanoparticles together in planned patterns.

Each nanoparticle is surrounded by a coating, or a layer of chains of atoms that prevents the gold nanoparticles from forming a larger hunk of metal. This coating also helps to bring the nanoparticles together in space in a process called self-assembly, through which they arrange themselves to form a weak surface a single unit thick. The surfaces consist of nanoparticles strung together to form a platform, like the foundation of a house. The more flexibility researchers have to arrange those atoms and the more tightly they're held together, the more options they will have to build structures on those foundations.

To create a variety of structures that are held together more strongly, Hanks has altered the chemistry of the coating on the nanoparticles. By making coatings that can be chemically bonded to each other using ultra-violet light, he and his students can "write" with nanoparticles. This flexibility to arrange the nanoparticles in different ways could give chemists and engineers greater tools to work with on a nanoscale.

"You use the trick of self-assembly to get these things to organize and then you use light to lock them into place," Hanks says. "You can make a more robust structure." Using different patterns of light in different situations gives researchers another tool to create specific patterns of nanoparticles tailored to a particular application.

In collaboration with professors at Clemson University, Hanks is working on a project that would imbed these coating molecules as sensors inside plastic materials, allowing researchers to test strain within the plastics as they work with them. Such sensors would give researchers immediate feedback about how materials are responding and at what point they might be failing.

One of the most challenging principles of nanotechnology has been the way it breaks down traditional barriers between the fields of biology, chemistry and physics. Biology serves as a model set of tools that work on nanoscale. Cells contain the blueprint genes leading to proteins, and those tiny proteins are like miniature factories, constantly processing food and carrying out the work of growing, moving and reproducing.

Chemists have always worked with atoms and molecules but without the specific control to make individual molecules do what they want them to do. Physicists have helped the process of analyzing and understanding the unusual properties of these materials. Success in nanotechnology involves developing comfort with elements of all three fields in new and creative ways.

Professor Jeff Petty and his students are investigating silver nanoparticles, using Mother Nature to help them in the

Known for his colorful personality, distinctive attire and innovative mind, Tim Hanks has built a research niche within the field of novel materials.

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form of DNA molecules. However, instead of using DNA for its original purpose as a biological blueprint, Petty and his cohorts are using the spiral staircase structure of the molecule itself and the shapes from more than one DNA molecule when they come together.

The DNA molecules form spaces that produce nanoparticles with specific numbers of silver atoms — anywhere from one to five atoms. "The evolution of this design is right on target," says Petty, a 1986 Furman graduate. "We kind of take and put things together and have some new ideas."

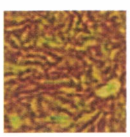
Petty and junior Caroline Ritchie are trying to understand how to control the number of silver atoms in each cluster. But they already see interesting potential applications of the nanoclusters.

For one, the silver clumps bind only to certain sequences of DNA, making them a possible sensor for genes that are involved in a disease. Even better, once Petty and his students can control the size, the smaller nanoclusters glow one color, while the larger ones glow another. The color difference gives them two different tools to track where molecules are moving within a cell.

In addition, cells are notoriously finicky about what molecules they'll absorb from the outside. The DNA could serve as a packaging material to introduce these nanoclusters into a cell before releasing them to find their specific targets.

Ritchie, who began working on this project during the summer after her freshman year, was excited to be involved in research so early in her college career. In November 2004, she won a second place award for a presentation at a regional meeting of the American Chemical Society.

"I enjoy putting all of the stuff I learn in classes to a practical use," she says. Laboratory courses are full of experiments that people have done before, she adds, "but when you're doing research you can discover whole new things."



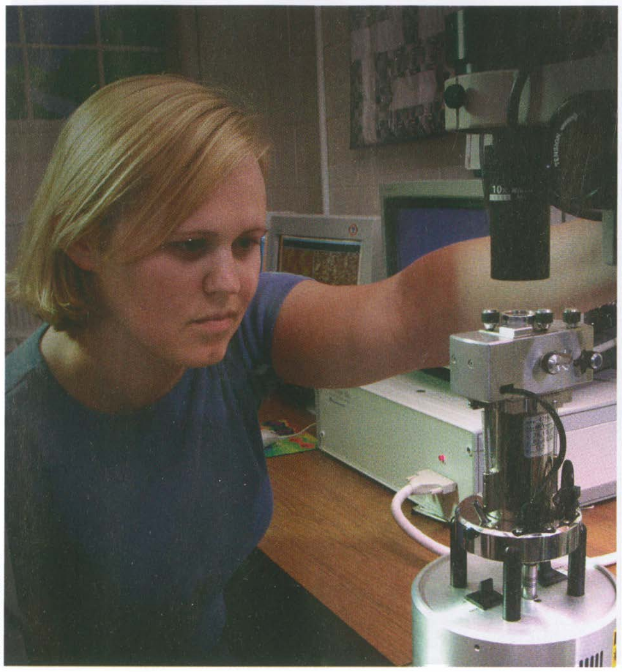
The critical challenge in making nanotechnology work has been the lack of proper tools to allow scientists to catch a glimpse into the world of the minuscule. And indeed, building something with materials you can't see would challenge even the best engineer.

"The bottom line is that we know atoms exist but we have never actually seen them," Hanks says. "But the atomic force microscope, even though it operates on a very different principle, lets you literally see atoms. And that has completely transformed our understanding."

Instead of magnifying with light, the way a microscope would, the atomic force microscope (AFM) is a tiny lever with a probe on its underside. The probe runs along the surface that you're examining, and the lever moves in response to the surface, like a needle on a record player. A tiny laser reflects off the top of the lever, and the angle tells the height of the sample. A computer then processes this data into a kind of surface map.

Because of her knowledge of the

Laura Glish has become so proficient with the atomic force microscope that she has been asked to train her fellow students in its use.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AFM, chemistry professor Laura Wright is nanotechnology's eyes at Furman. She first learned about the AFM in 1989, when the technique was still very new, during a bus ride to a Gordon Conference, an annual forum where groundbreaking research in biology, chemistry, the physical sciences and related technologies is presented and discussed. She then spent a sabbatical year at the University of Arizona learning how to use it.

Recognizing the power of this tool, she convinced chemistry department chair Lon Knight that such an instrument was worth Furman's investment. Given Wright's technical expertise with the AFM, almost all nanotechnology work in the department crosses her doorstep for her input and hands-on assistance in analyzing new materials.

Because of the availability of the AFM at Furman and the Hanks group's need to analyze some of their polymers (repeating patterns of small molecules strung together in long chains), Laura Glish first took on the project of working with the AFM in the Plyler Hall basement during the summer after her freshman year. Glish, who conducts research with both Wright and Hanks, learned all about the AFM from Wright, but is using the images that she has visualized to help with the design of new materials in the Hanks group. Her work with the two different groups is symbolic of the interdependence that nanotechnology demands of researchers.

Wright's expertise with the AFM has also opened scientific doors that she never expected, such as analyzing the polymers in plastic films and other packaging. Because the instrument allows her and her students to look at the actual surfaces, she can give companies a birds-eye view of what these materials look like up close. With the knowledge gained from such research, companies can create packaging that keeps food fresh by allowing certain molecules in and keeping others out. In their work with Mitsubishi Polyester Films in Greer, S.C., Wright's group has also studied plastic coatings for glass that will make it bulletproof.

But in addition to the very practical research that students working on these projects are able to do, they have the chance to see how their work applies outside the academic laboratory. Students involved in the project with Mitsubishi actually go to the plant and watch the molten plastic being stretched and flattened. "The students going to the pilot line, their eyes just get huge," Wright says. " 'Oh my goodness, is this what industry does? Wow, I never knew.' "

Wright and her collaborators at Mitsubishi have set up a unique opportunity for her research and for the company to gain useful insights. "Nobody else is doing AFM on samples like this, where they know the total history of their sample. I know exactly which way the thing was stretched on the production line. I know how much it was stretched. I know which side was in contact with air and which side hits the cooling drum, and I can see the effects of the different sides of the film and how it's produced. No one else has ever been able to correlate that," she says. "It's just been such fun."

Wright is on sabbatical this year and plans to work part time for Mitsubishi.

In other collaborations, David Johnson '04 worked with researchers at Michelin to determine how different layers of rubber in tires came together.

With the help of Laura Wright's research, companies can create packaging that best protects and preserves their products.

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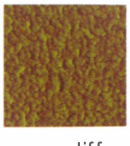
Johnson also worked with Kemet Electronics to study the smoothness of the metallic inks the company was printing on its electrodes.

"I'm a pretty practical-minded person. The most interesting thing to me was the end result," says Johnson, a Fulbright Fellow in Germany in 2004-05 who is now a researcher at Georgia Tech. "My roommates have Michelin tires, and I might have had something to do with developing them."

Bob Posey '69, a staff chemist at Mitsubishi Polyester Films, brought Wright some samples at an early AFM training session that Furman sponsored for local industry representatives. He marvels at how careful Wright and her students are and how fruitful the collaboration has been.

"Laura's good about not reading into these images that you get from an AFM," he says. "If you want to see something there, you can probably see it. The trick is, is it real? She's good about sorting all of that out."



For Furman students, the nanotechnology push represents an opportunity to do many different types of research during their undergraduate careers.

In addition to learning how to use the AFM, Glish has synthesized some of the same polymer materials that she has analyzed. This summer she worked on a completely different project in the Hanks group, studying different types of bonding by growing crystals and doing computer modeling. But her AFM skills did not go to waste, as she continued to run samples for Wright and helped train the next generation of Furman's AFM users.

While developing her technical expertise, Glish has also established close working relationships with her two advisors. "Dr. Wright is like my mom away from home," she says. "She's become a mentor to me, and I adore her." She describes Hanks as a "kooky" guy: "He's an amazing chemist, and he thinks so outside the box that it's scary. But he's a smart guy and really friendly, and it's just really been a good environment for me personally."

Glish is considering graduate work in chemistry or materials science but is still uncertain as to whether she'd prefer a career in research or academics.

About the future of nanotechnology, however, she is anything but undecided. "I really think it's going to be — well, it is already, I think — the next huge thing in science, and a lot of research and money and energy are going into making things smaller and making things faster," she says. "But I think it's just a field that more people will get into in the next few years when they really learn about all the amazing things that you can do."

The author, who graduated from Furman in 1996 with degrees in chemistry and German, spent a year as a Fulbright Fellow in Germany before earning a Ph.D. in chemistry from Indiana University. She lives in New York City and works as a free-lance science writer. She has written for Discover, Astronomy *and* Science News for Kids.