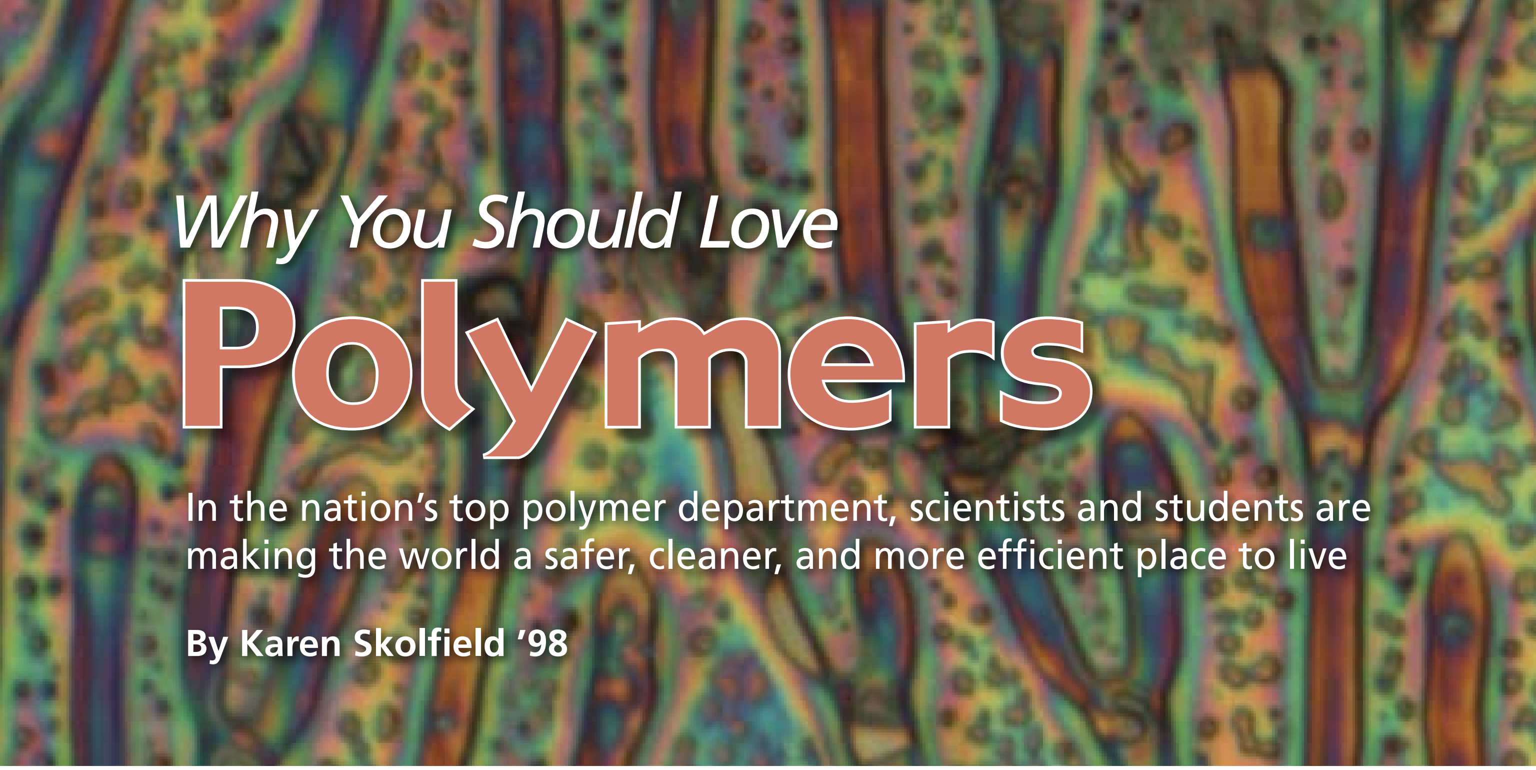


Why You Should Love Polymers

In the nation's top polymer department, scientists and students are making the world a safer, cleaner, and more efficient place to live

By Karen Skolfield '98

It's James Watkins, one of five faculty that I interview to learn more about polymers, who asks if I know what a polymer is. I flub the answer because the first embarrassing thought that comes to mind is a line from the film *The Graduate*: "Just one word: Plastics."

Though that's not untrue, it's not the whole story. Polymers may be natural (cotton, wood) or not (nylon, Teflon, the much-loved Silly Putty) and are long-chain molecules comprised of repeating units, called mers, linked together. The beauty of polymers is their low production costs and desirable characteristics; scientists are able to manipulate polymers to produce substances useful in medicine, energy, electronics, fire safety, filtration, and more. What most of us know about polymers is woefully small— professor Ken Carter complains to me that many people ask him if he works on plastic soda bottles and recycling—and so I set off to our top-ranked Department of Polymer Science & Engineering to learn more. With just 15 faculty and 210 graduate and post-doctorate students, the department has been ranked number one by *U.S. News & World Report* and number two out of all materials science departments by the National Research Council.

According to Department Head Shaw Ling Hsu, the future of the department can be viewed as falling into three new areas of research: energy, biomaterials, and microelectronics. When I ask Hsu for the names of faculty to interview, he gives me four of the newest to the department, with the understanding that in doing so, I'm leaving out a large chunk of what goes on here. I begin knocking on doors.

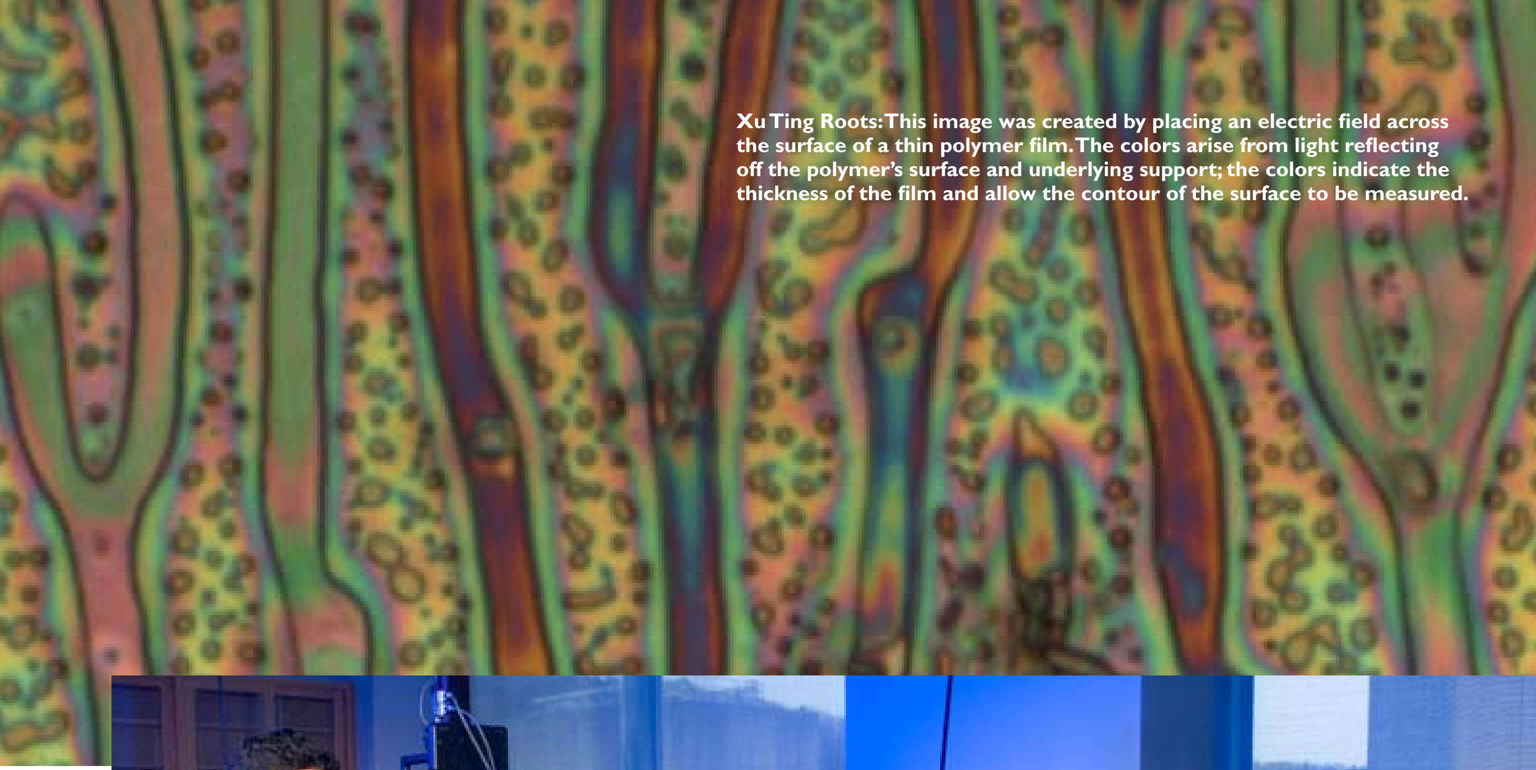
The Biomaterials Frontier

I interview Gregory Tew on the day the 2005 Nobel Prize in chemistry is awarded to three scientists for their work on metathesis, a reaction that has broadly influenced polymer research, and the entire Conte building buzzes with the news. Tew can't wait to talk about the role of polymers in the medical field. "I have a great project for that," he says.

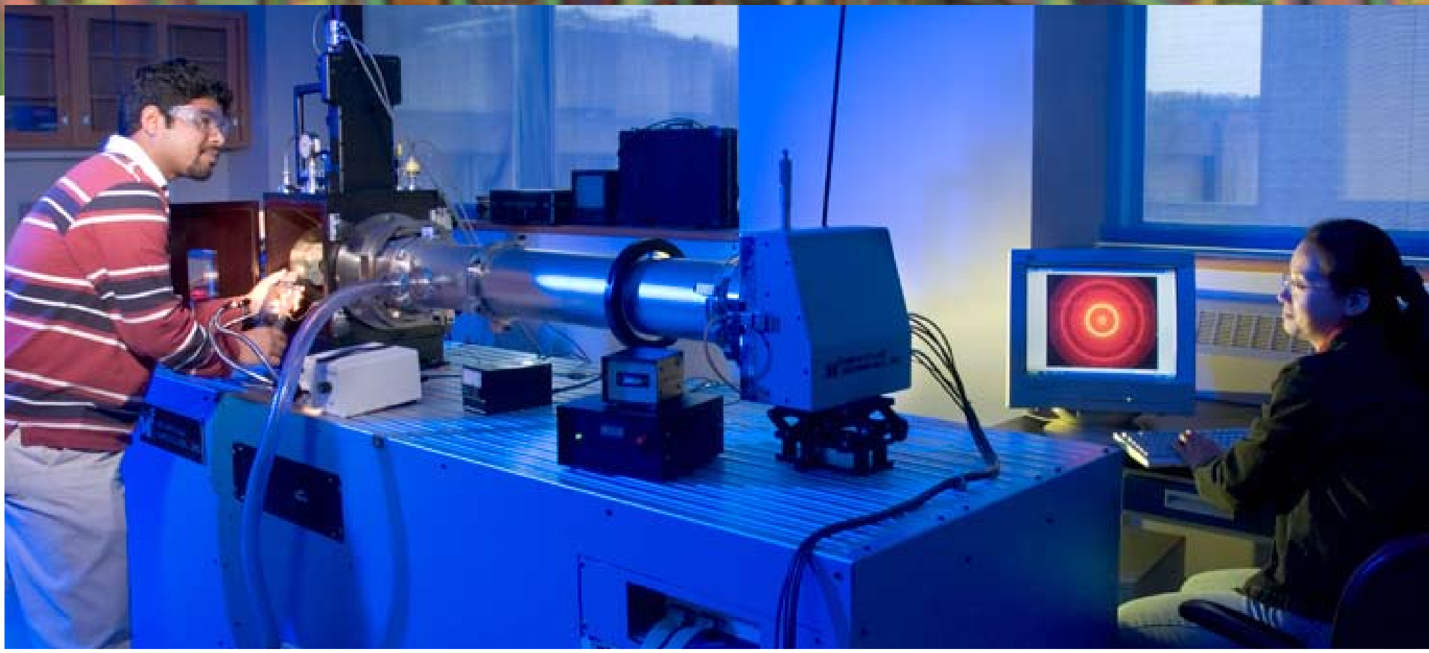
Tew and his students are targeting hospital-acquired infections, those nasty "so-you-think-surgery-was-bad" bacteria. Specifically, Tew works on antibacterial polymers to be used in medical devices such as catheters, with the hopes of saving a good percentage of the 50,000 people that die from catheter-related infections each year in the United States.

Multiply 50,000 people by five years. Multiply that by the one person you know who's had complications from hospital-acquired infections. "Almost everyone knows someone who's had complications," he says. "To have a project with very real-world, near-horizon benefits to society is fantastic."

In his laboratory students are at work forming blends—catheter tubing mixed with an antibacterial polymer from his lab. They'll be recast as tubing and sprayed with bacteria. From here, he says, there are numerous hurdles to overcome such as long-term toxicology and inflammatory and allergy responses. Thus far, Tew says there is no bacterial resistance to his polymer blends. "It appears to be more difficult (for resistance to develop), though I'd never say it won't happen," he says.



Xu Ting Roots: This image was created by placing an electric field across the surface of a thin polymer film. The colors arise from light reflecting off the polymer's surface and underlying support; the colors indicate the thickness of the film and allow the contour of the surface to be measured.



Across from his office, someone's hung photocopies about the three Nobel Prize winners. It might be what prompts Tew to look so hard at the future: "I think in 10 years you'll be able to take a polymer and make it a drug," he says, "to go beyond anti-microbial toward pharmaceuticals. That could impact all sorts of areas—heart disease, cancer, degenerative diseases."

Some biomedical polymers stay in the hospital; others you get to keep for a while. Shaw Ling Hsu researches stents, small mesh tubes that are threaded into arteries to keep blood flowing. The benefits of stents are enormous, as they are used to prevent heart attacks and stroke and are just one-fifth the price of corrective surgery.

But stents are not without their problems, including rejection and the re-closure of the artery. Enter polymers.

The polymer coating on current metallic stents often breaks down too quickly in the body. Rejection rates are high, and rejected stents must be surgically removed. "We're trying to understand this process and manipulate the structure of the polymer-drug material to control the drug release rates," Shaw says.

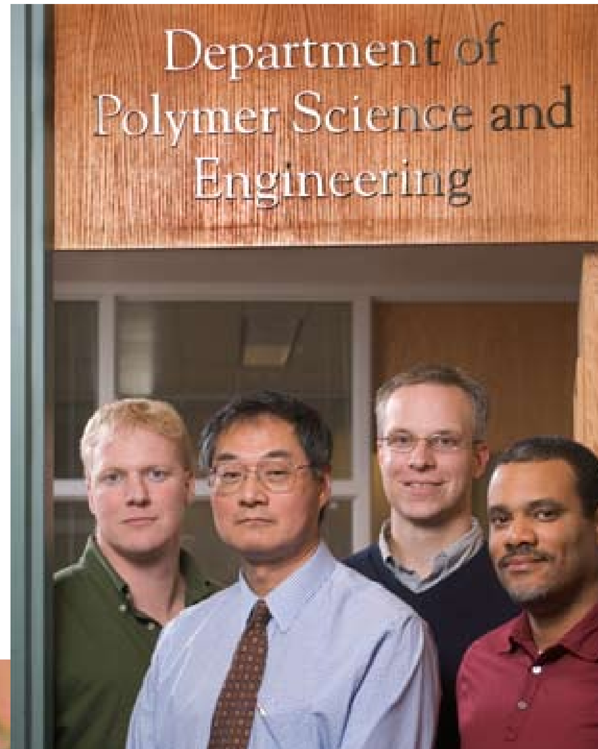
Shaw and others in the department, including professors Todd Emrick and Murugappan Muthukumar, are at work on a new stent. The polymer coating is infused with an anti-rejection drug and is designed to activate based on body temperature, thus releasing the drug in a controlled fashion rather than all at once.

Shaw keeps a mesh stent in a tiny bottle on his desk, and hands it to me. It looks like a gold scaffold and can be collapsed to fit through an artery, then expanded when it reaches the section in need. "It's a very clever device," he says. "I had no idea how clever until I got involved."

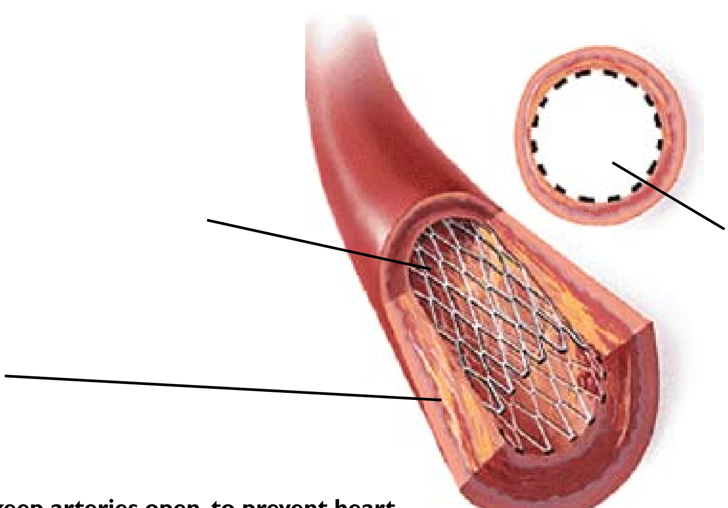
The next step? Shaw and his coworkers are working to develop all-polymer stents that won't be rejected. Polylactic acid, the most desirable polymeric candidate, biodegrades into lactic acid which occurs naturally in the body.

Shaw stage-whispers to me: "I've never even had biology! But it's such a fascinating area."

One of professor Alfred Crosby's areas is adhesion: "It's something we use every day but as a science we don't really understand a lot," he says. "Even down to things as mundane as Scotch tape, you wonder why it works."



Polymer scientists Ken Carter, department head Shaw Ling Hsu, Alfred Crosby, and Jim Watkins are leading research in such areas as biomaterials, nanotechnology, and microelectronics.



Stents are clever devices used to keep arteries open, to prevent heart attacks and strokes, at a fifth of the cost of surgery. Shaw Line Hsu and others UMass Amherst researchers are developing polymer coatings for stents infused with anti-rejection drugs.

He shows me a magnified image of Scotch tape, and on this scale the adhesion looks like blooms of algae spreading across a tidal pool's surface. "They're called fingers," he says. "Patterns are all over in cell adhesion."

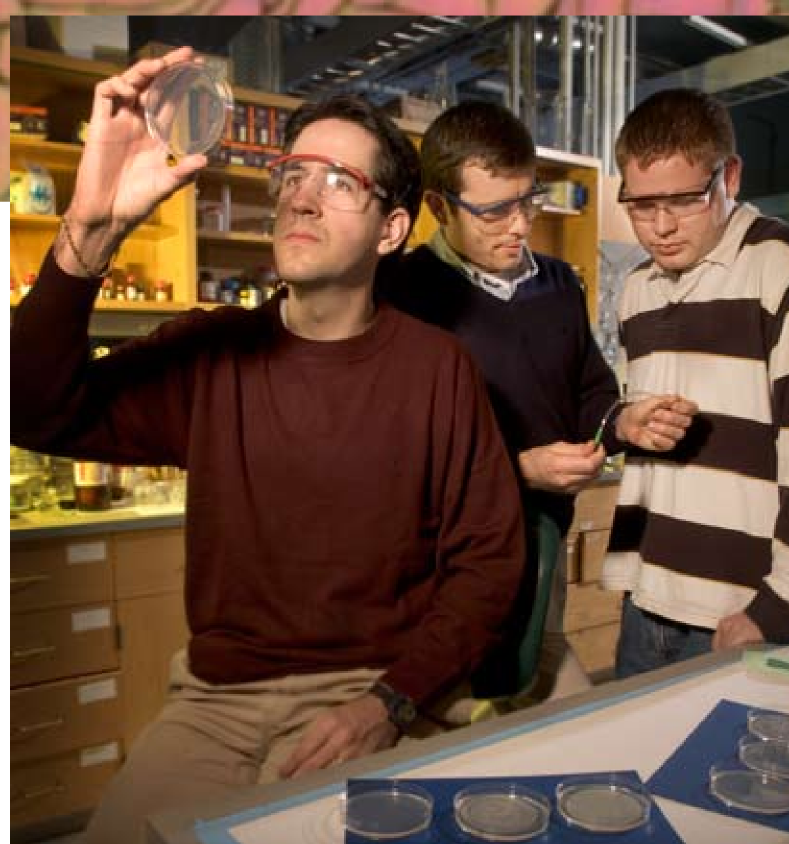
These patterns are being studied and manipulated by Crosby and his colleagues. Adhesion patterns occur often in nature: The feet of the gecko and other animals, such as the jumping spider and common housefly, are covered with a pattern of tiny hairs. Walking on the ceiling—no problem. It's a tantalizing ability to those that study adhesion.

Aside from Scotch tape and the possibly less-useful ability to walk on the ceiling, adhesion has numerous areas of application, including anti-fouling coating for boats and pipes, as scientists learn to disrupt the adhesion pattern of mollusks and barnacles; transdermal drug delivery (think birth control and nicotine patches) with a different adhesive pattern required for each drug; adhesive patterns to spontaneously release paint or varnish and thus cut the use of environmentally noxious solvents; and cell sheet harvesting, where seed cells from the cheek are grown on a hydrogel solution.

It's the last example of adhesion that is motivating the most recent work in Crosby's lab as students prepare hydrogel solutions and blow miniscule bubbles into them. The bubbles will cause the cell sheet to lift from the hydrogel.

This information will help in the development of cell sheet harvesting, which eventually could lead to corneal transplants and bladder and liver repair. "The lift-off process is based on the control of adhesion," Crosby explains. "Hopefully, our expertise in this area will aid the development of this critical process and extend it to a wide variety of cell lines."

The Electrostatic Basket: What looks to be a woven basket is an optical micrograph of a polymer film made unstable by using an electric field. The strands are microscopic hills of polymers about the size of a human hair.



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“They’re like people in an elevator, trying to maintain their personal space.”

–Professor Jim Watkins, on polymers of different compositions. Watkins co-directs Mass Nanotech, the campuswide nanotechnology research institute.

Microelectronica

“This’ll give you the scale for all things nano,” Jim Watkins begins, and hands me a printout. It’s a scale with its high point at one centimeter and its low point dipping below a nanometer, or 10^{-9} meters. To even begin to think of something this small, I’m reduced to dividing the tangible: A human hair is 60,000 nanometers wide. A red blood cell is 2,000 nanometers across. Basic physical properties, such as conductivity and flexibility, are often changed on the nanoscale. Frankly, even thinking about it makes my head hurt, and I tell this to Watkins, who also serves as the co-director of MassNanoTech, the campuswide nanotechnology research institute.

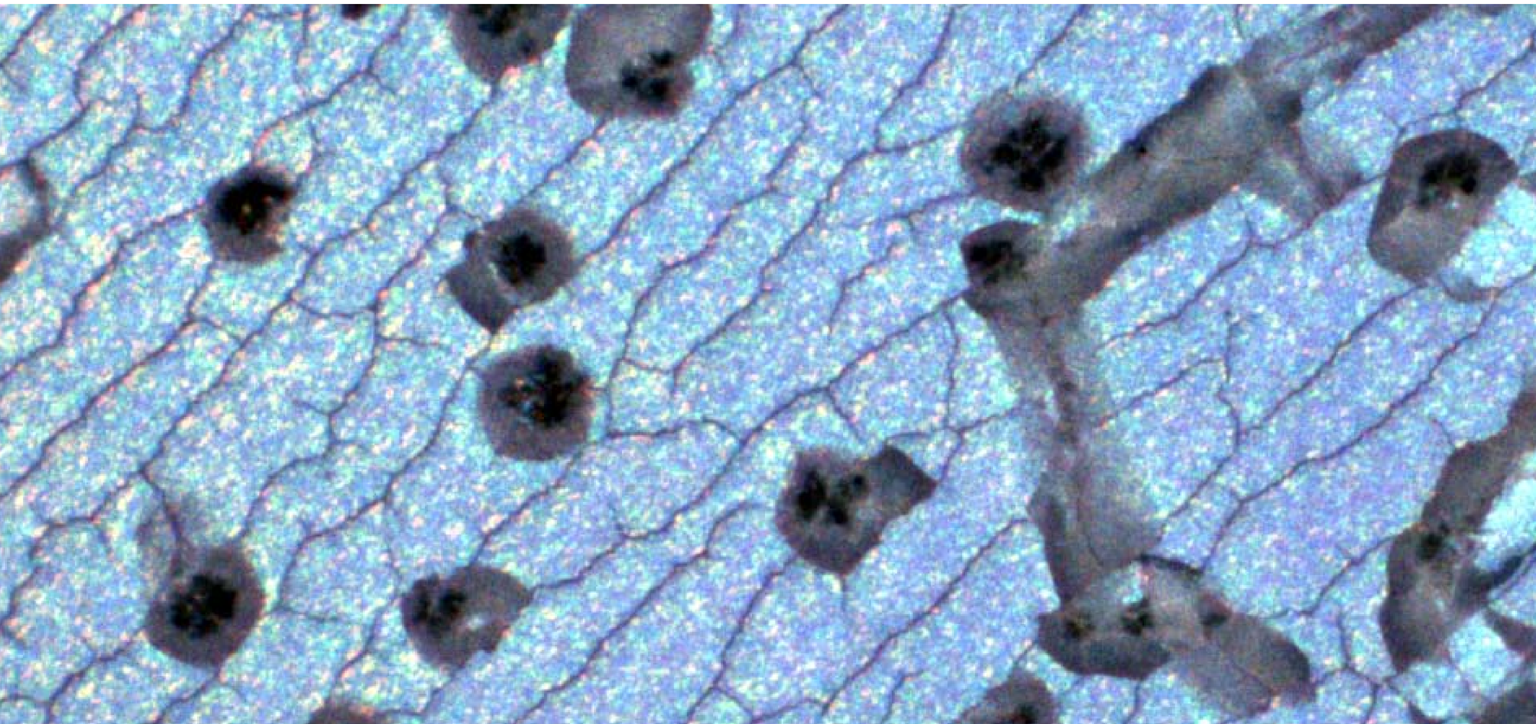
Thinking on this scale does not seem to bother Watkins and Ken Carter, who are schooling me in nanotechnology and microelectronics. Watkins loves the challenge of this scale: “How do you build things 1/60,000 of a human hair? And how do you build devices and systems of many interconnected nanostructures rather than one in isolation?”

And just as importantly, Why?

Carter answers this for me, by tapping on the computer. A computer chip, he explains, is the size of a fingernail. If that fingernail-sized chip were the size of the entire United States, defects would be equivalent to the size of a car. Defects the size of a single pothole will soon be able to ruin a chip. In the mad dash to keep up with competitors, computer manufacturers must worry about those nano-sized potholes as they increase the computer’s speed, all while trying to keep costs down.

Along with other lines of research, Watkins, Carter, and colleague Thomas Russell work on how to build the information “highways” of our computer chip blown up to country-size proportions. Some of this building, Watkins explains, starts with understanding the behavior of polymers.

“Polymers of different compositions generally don’t want to be next to each other,” Watkins says. “They’re like people in an elevator, trying to maintain their personal space. They make themselves as small as possible and form these beautiful ordered morphologies. I can control the morphology in an ordered array, into cylinders, spheres, or stacked



sheets." This method of controlling the morphology, or structure, is called the bottom-up process, as the structure is generated by itself. The process may eventually find its way into the areas of biosensors, such as medical diagnostic tools, and photovoltaics for harvesting solar energy.

Carter's method of creating re-usable patterns on the nanoscale is called imprint lithography. "It's the old-fashioned idea of printing," he says. "We make a mold of nanoscopic features we want and print these onto wafers. It's very inexpensive, and it gives us the ability to design computing devices that operate on a nanoscale."

Most important to this process is the ease with which the computing devices may be replicated. "It wouldn't be useful as a onesie-twosie kind of thing," Carter says. "We're saying we can reproduce billions of these things in one print. There's lots of neat-sounding stuff out there that people have no idea how to make work. My work is the pursuit of making useful small things. How do you take these great ideas and put them together in a way to make it useful instead of a research curiosity in some dark lab somewhere?"

In Carter's office, to the right of his computer, hangs the famous M.C. Escher print "Waterfall," with its impossible paths that fool the eye and brain as if the third dimension were a negotiable state of being. The print might as well be an analogy for the departmental research in nanotechnology where, as it turns out, nothing behaves like the world as we know it.

I meet with Department Head Hsu a final time to discuss one more area of inquiry in the department: environmentally appropriate materials. Along with colleagues Bryan Coughlin , Todd Emrick, and Tom McCarthy, Shaw hopes to develop or refine uses for waste products such as wood chips and corn stalks. He's also at work on alternative processing along with colleague Alan Lesser, as they try to phase out solvent-based coatings and adhesives.

Take the humble wood chip, long considered a waste product of the wood manufacturing and paper industries. Efforts are being made to turn wood waste into energy through biorefineries, and wood chips are being used in beams made from a wood and polymer blend.

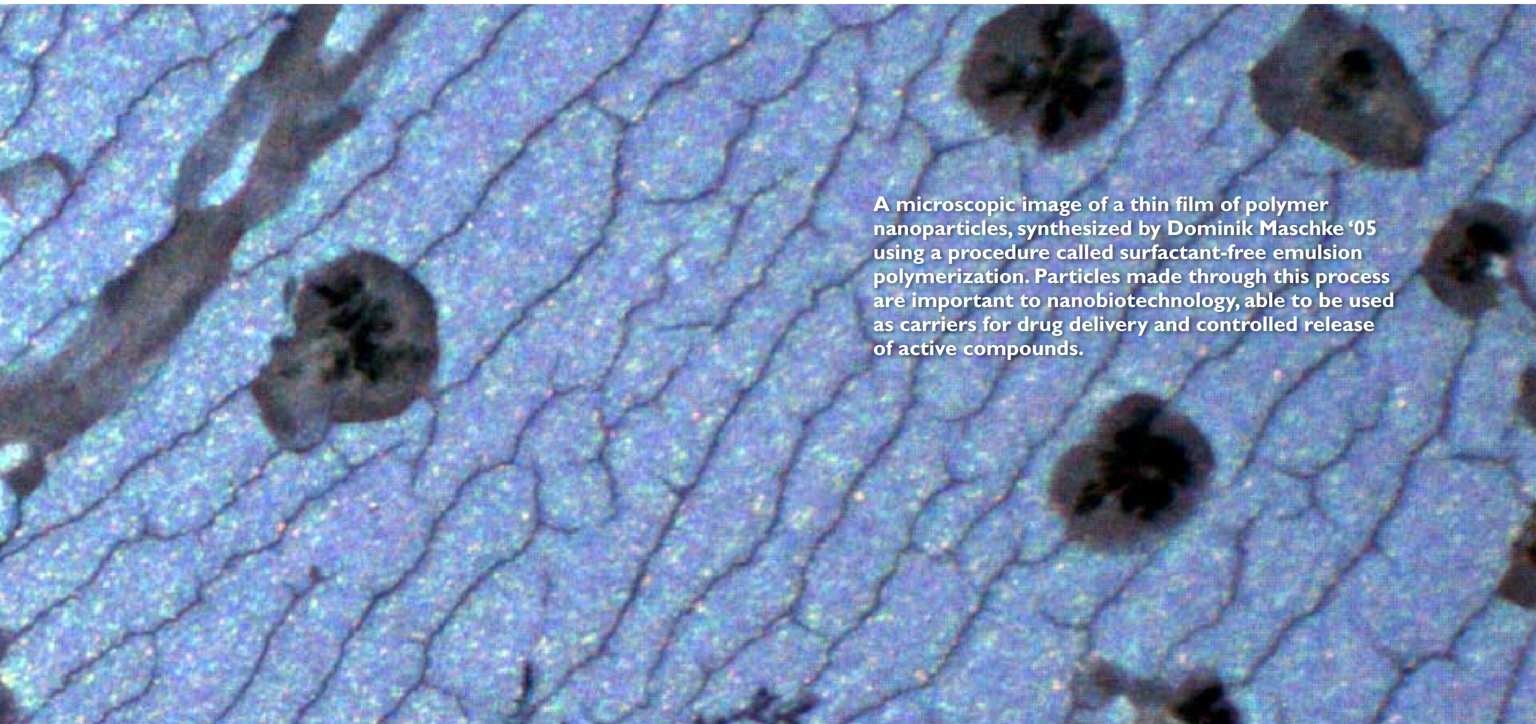
"We want to use as much wood and as little polymer as possible [in the composite beams]," Shaw says. "Right now it's about 50/50, and you want to use as much [wood] waste as possible."

The problems with changing this ratio are legion, however. "You must create a bond between the polymer and the wood surface," he explains. "You want a nice feel to the beams. The beams must withstand heating and freezing," a tall order given that polymers and wood react to temperature extremes and outdoor conditions in different ways. Polymers, for example, repel water, while wood soaks up water and expands.

Instead of creating a polymer that can perfectly mimic the properties of wood, Shaw hopes to modify the wood. "Can we build in a coating onto the surface of the wood that repels water, or a penetrant into the wood to repel water?"

Halfway through our discussion, Shaw stops and laughs. "Did you ever think all this happened in polymer science?"

Truthfully, no. And it's just a portion of what goes on. ◆



A microscopic image of a thin film of polymer nanoparticles, synthesized by Dominik Maschke '05 using a procedure called surfactant-free emulsion polymerization. Particles made through this process are important to nanobiotechnology, able to be used as carriers for drug delivery and controlled release of active compounds.