Juan Hinestroza and Margaret Frey are pushing the textile frontier by developing nanofibers to act as biological sensors and shields against viruses, bacteria, and hazardous particles.

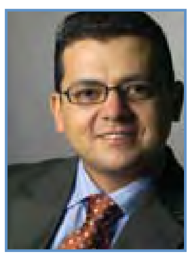
Nano-Textiles Are Engineering a Safer World

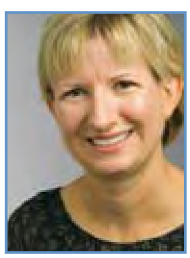
BY CLARE ULRICH

Stone, bronze, and iron have transformed human civilization so dramatically that major time periods are identified with them. Juan Hinestroza, an assistant professor in the Department of Textiles and Apparel (TXA), believes that nanotechnology will revolutionize the near future in much the same way.

Hinestroza and his TXA colleague Margaret Frey, the Lois and Mel Tukman Assistant Professor, are using nanotechnology to create radically new textiles and to enhance conventional textiles with greater functionality. Hinestroza calls what he does a "technological oxymoron."

"People perceive textile manufacturing as an old technology, but it can provide the bridge to making nanotechnology a commercial reality," he explains. "What I'm doing is merging two revolutionary technologies that are 200 years apart (textile technology and nanotechnology), complementing the old technology with new developments in science. I say 'revolutionary' because both technologies have changed the way we see the world."

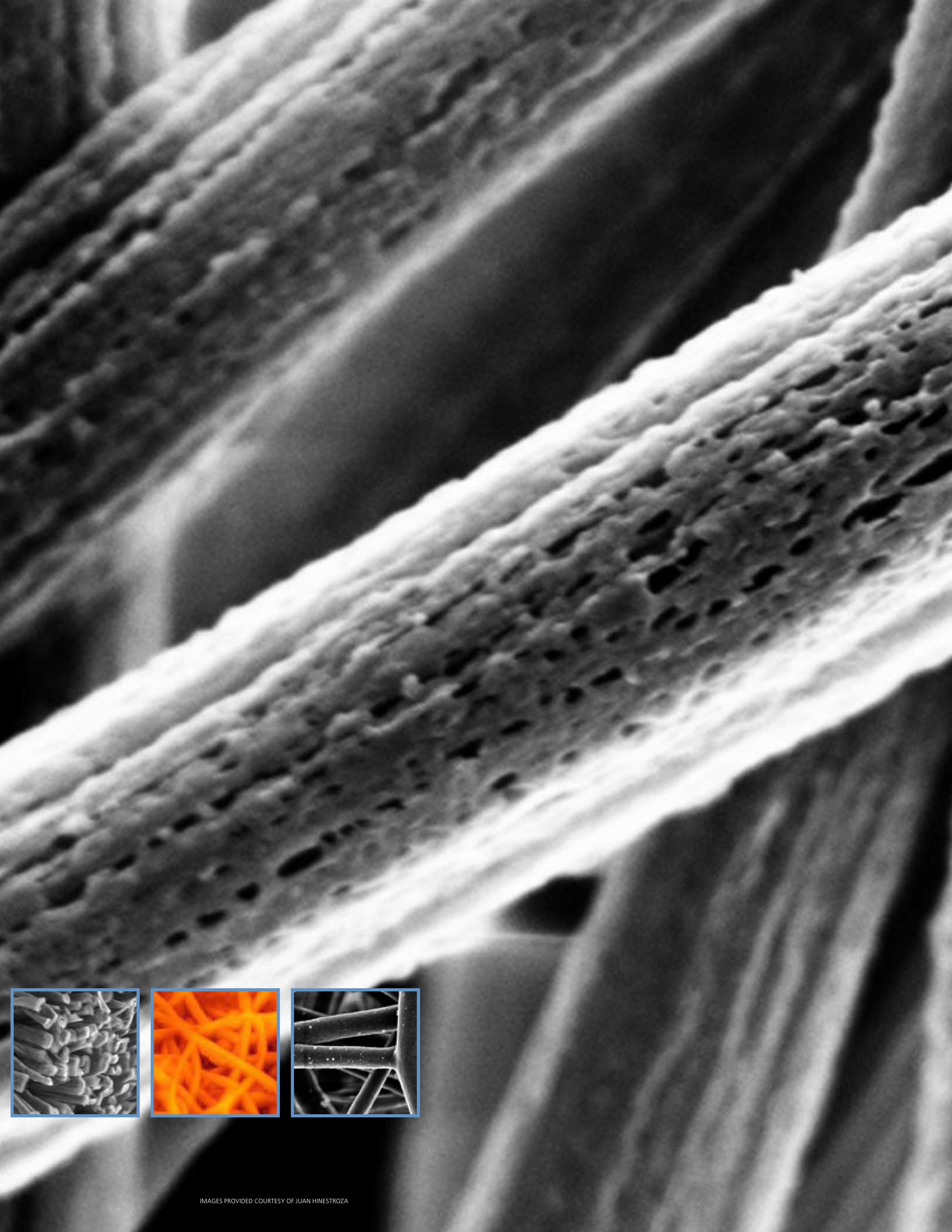




Having joined the College of Human Ecology faculty in January 2006, Hinestroza is developing remarkable fibers potentially capable of filtering out viruses, bacteria, and hazardous particles too small to see with the naked eye. He received a John D. Watson Young Investigator Award from the New York State Office of Science, Technology, and Academic Research in 2005 to expedite this work, which is being done in collaboration with scientists at the Centers for Disease Control and Prevention (CDC).

"It was humbling to get that award," Hinestroza reflects, "because the award is named in honor of James Watson, who received the Nobel Prize for discovering the structure of the DNA, and he's still alive." Hinestroza also receives support from grants of the National Science Foundation and the U.S. Department of Commerce. > > >

Large photo: Ultra-porous polyacrylonitrile nanofibers with silver nanoparticles are developed for antibacterial applications. The nanofibers were produced via electrospinning and a sacrificial polymer.



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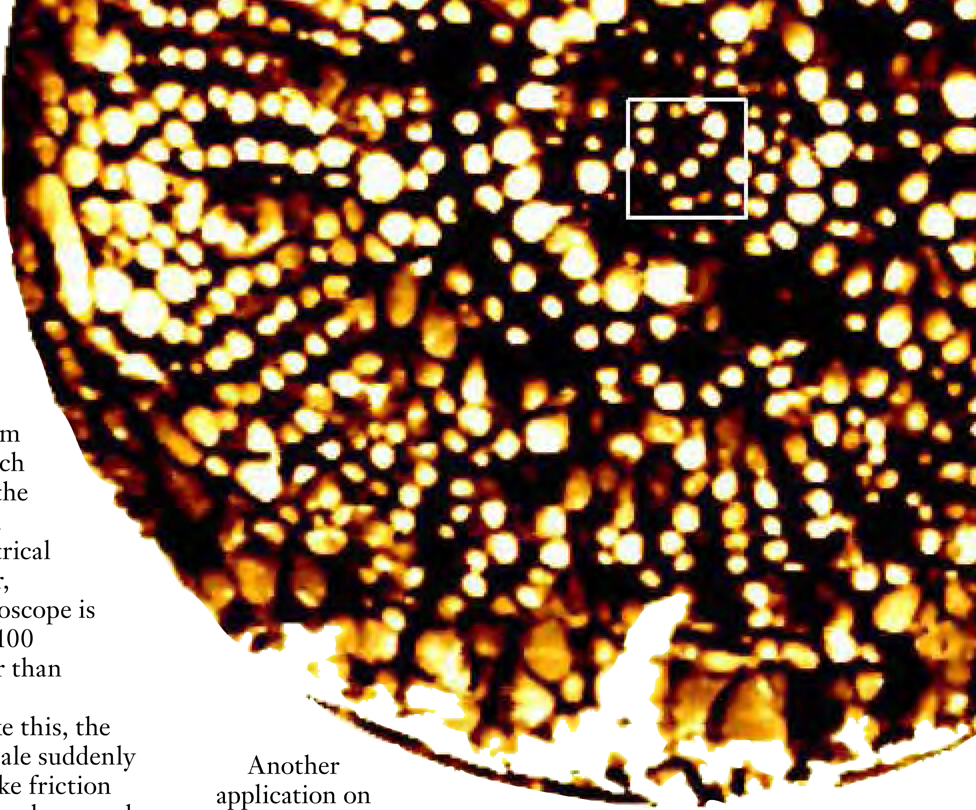

Merging the old and the new, Hinestroza uses a process called electrospinning to create the fibers from which he constructs his much-in-demand biofilters. Electrospinning has been around since 1934 but has been used on the commercial scale only since the early 1990s. It involves dissolving a polymer—either a natural polymer derived from plant-based cellulose or a synthetic polymer such as nylon or polyester—in a solvent, squeezing the liquid polymer solution through a pinhole, and applying high voltage to the pinhole. The electrical field pulls the polymer solution through the air, stretching it into a tiny fiber. An electron microscope is needed to see these fibers, which are less than 100 nanometers in diameter, or 1,000 times smaller than conventional fibers.

"Once you get to a really small-size scale like this, the forces that dominate everyday life on a large scale suddenly become much less important, and properties like friction and flow past objects that are less significant on a large scale become the dominant terms," Frey explains. "Nanoscale fibers are roughly equivalent in size to air molecules. So if we're looking at filtration devices, nanofibers make very effective filters because they don't get in the way of the air flowing past them. And less power is needed to push the air through the filter because the volume of the fibers isn't blocking the air flow."

Ingenious modifications Hinestroza has made to the electrospinning process enabled him to create his supersensitive biofilters. By manipulating magnetized nanoparticles in a magnetic field during electrospinning, he can direct the flow of the polymer and target chemical molecules to deposit layer after layer onto the surface of the electrospun fibers. The advantage is that both the size and the position of the nanofibers can now be precisely controlled.

"Because of the combination of the small size of the fibers and the electrical fields created between the fibers, we are able to capture particles in the 100- to 300-nanometer range," he explains. "It just so happens that that's the size of viruses and bacteria."

It is expected that these novel filters will provide protection against infectious agents that cause severe acute respiratory syndrome (SARS) and avian flu. However, the process can be customized to serve a variety of purposes. By applying nanolayers to natural fibers, for instance, Hinestroza can produce protective clothing that selectively blocks hazardous gases and minuscule contaminants but allows air and moisture to flow through so that the wearer can sweat and feel comfortable. Users who might appreciate this kind of gear are firefighters, emergency responders controlling a biohazard threat, or military personnel on duty in hot climates.

"Fashion designers see garments as an expression of creativity," Hinestroza muses. "Chemists and materials scientist see garments as a collection of molecules. Now we can take these molecules and create fashion with function." It's just a matter of time before lightweight smart textiles like these are being used by hikers and other athletes, or even by environmentally sensitive individuals.

Another application on the horizon is controlling the movement of medicine through fibers.

"Some companies are interested in using this technology to administer time-released antibacterial and antiallergenic compounds," Hinestroza claims. "So you could have your arthritis medicine while you're wearing your gloves." Or one might soon encounter antibacterial sheets in hospitals or military barracks that could help prevent the spread of illnesses where lots of people are confined to small, common spaces.

Even the law is going nano. Hinestroza is able to embed magnetic nanoparticles inside a garment or paper document that create a unique but invisible signature, which could be scanned, for example, to detect counterfeit currency, fake passports, or even knockoff designer clothing.

Textiles as Sensors The unique characteristics of nanofibers—such as greater surface area and porosity—got Margaret Frey thinking about fabricating a textile that could act as a sensor. She envisions a material, perhaps something that looks like a sponge, that anyone could easily use to swab a piece of fruit or meat, or wipe a food or surgical preparation surface, to detect the presence of hazardous bacteria such as *E. coli* or anthrax. If the contaminant is detected, the fibers would capture it and alert the user by changing color or becoming fluorescent.

"The idea is to create something that people without a high level of training can use fairly quickly," Frey says. "A lot of very good detection screens already exist, but it takes a week or longer to get analyses back from the lab. By then a victim has already suffered the effects of eating contaminated food or undergone some kind of potentially unpleasant treatment—whether or not he or she was actually exposed. We'd like to create something that has enough sensitivity to alert users instantaneously to a problem so that they can either take immediate steps to protect themselves or know for sure that they haven't been exposed. If you can determine that a workplace has not been contaminated with anthrax, then people wouldn't have to lose work time."

Polyester nanofibers are encapsulated into a polyethylene macrofiber. These nanofibers were created via bicomponent extrusion allowing the manufacturing of thousands of nanofibers in large quantities.

On another project that makes creative use of the high surface area of nanofibers and their ability to absorb more liquid than conventional fibers, Frey is collaborating with two scientists in Cornell's College of Agriculture and Life Sciences—Mike Hoffmann in Entomology and Alan Taylor in Horticultural Sciences at the Geneva Experiment Station—to create a polymer tailored to absorb pesticides or herbicides. Fibers saturated with time-released pesticide could be planted with seeds as an alternative to spraying the pesticide. The goal is to develop a textile that would not only biodegrade by the end of the growing season but would replenish the soil with nutrients as it degrades.

"Our strategy is to enable growers to place the right amount of pesticides exactly where they want them to go, with none of it dispersing into the air, getting deposited on the playground, or running down the hill into the stream as it can when it's sprayed. Farmers would use less pesticide, and the pesticide would be doing its job and nothing else," Frey says. The project is far enough along for her to pilot-test it next summer.

Frey and TXA colleagues Kay Obendorf and Ann Lemley have teamed up with Alan Hedge in the Department of Design and Environmental Analysis to try to enhance objects that already exist in the built environment with the ability to cleanse the air around them.

"Did you ever feel like there's just not enough air in airplanes?" she asks. "We're exploring the idea that the doilies over the passenger seats or seat cushions or wall hangings could continually absorb particles or gases or other biohazards from the air—maybe even viruses—without using any energy." In addition to measuring what actually gets caught in the fabric, the group plans to survey people using these environments to see if they perceive cleaner air.

The team received a seed grant from the college to begin the project. When that grant expires at the end of a year, they expect to have enough data to apply for external funding to continue the study.

Frey and Hinestroza are both members of the Cornell Center for Materials Research (CCMR), a facility that offers them shared work space, access to high-powered, specialized equipment, and opportunities for interdisciplinary collaboration with university and industry researchers. Using many facilities at CCMR, Frey recently completed a two-year project with CLARCOR, a commercial provider of filtration products and services, where she and a CLARCOR technician developed fibers that improved the performance and energy efficiency of the company's air filtration systems. The partnership's success can be measured by the patent and two published papers that resulted from the project—and that CLARCOR recently hired one of Frey's student researchers who had worked on the project from the beginning.

Although collaboration between Frey and Hinestroza so far has been limited to experimentation with cellulose solvents, their overlapping interests are likely to lead to future partnerships. Frey is currently working with other Cornell researchers from the Department of Biological and Environmental Engineering and Department of Chemical and Biomolecular Engineering on incorporating biosensors into electrospun cellulose fibers. Her work parallels Hinestroza's in this area, and she uses some of the measurement tools he has developed.

Hinestroza is right about nanotechnology revolutionizing our world. With its promise to deliver precision materials with fewer defects and greater functionality, it won't be confined to the lab for long.

"I think in five years nanotechnology will change many of the products we use," Hinestroza predicts. "Nanotechnology will no longer be a commercial anomaly. Many of the phenomena we're seeing now were predicted in the 1960s, but we just didn't have the tools to make them happen. Now we have the tools, and hopefully we're predicting things that will happen in the near future."

He estimates that within a decade nanotechnology will have a market impact of hundreds of billions of dollars, and textiles will occupy an important share of that market. ●●●

Nano in the Near Future

These applications of nanotechnology in creating novel fibers and textiles are either already materializing or likely will be in the future:

- supersensitive biofilters made of fibers capable of filtering out viruses, bacteria, and hazardous particles;
- nanolayers applied to natural fibers and then made into protective clothing for firefighters, emergency responders, and military personnel that selectively blocks hazardous gases and minuscule contaminants but allows air and moisture to flow through;
- lightweight smart textiles for hikers, athletes, and environmentally sensitive individuals;
- fibers that control the movement of medicine to administer time-released antibacterial and antiallergenic compounds; for example gloves that deliver arthritis medicine or antibacterial sheets in hospitals;
- magnetic nanoparticles embedded inside a garment or paper document to create a unique signature that can be scanned to detect counterfeit currency or fake passports;
- sensors that could swab a food or surgical preparation surface to immediately detect the presence of hazardous bacteria;
- biodegradable fibers saturated with time-released pesticides that could be planted with seeds as an alternative to spraying pesticides;
- doilies, seat cushions, or wall hangings used in airplanes that would continually absorb particles or gases or other airborne biohazards.

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