Providing power for nanometer-scale devices is one of the most significant challenges facing nanotechnology today. By harvesting energy from the environment and converting it to electricity, nanogenerators developed at Georgia Tech offer a possible solution.

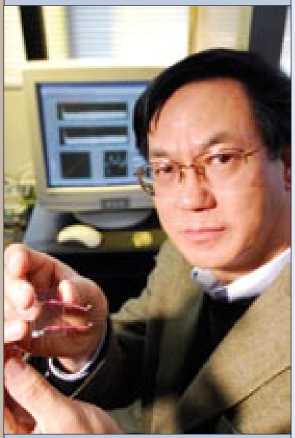
Power Shirt:

Fiber-based Nanotechnology in Clothing Could Generate Electricity by Harvesting Energy from Physical Movement

By John Toon

Photo: Gary Meek

Regents' Professor Zhong Lin Wang holds a prototype microfiber nanogenerator.



Nanotechnology researchers are developing a microfiber nanogenerator able to generate electricity to power small electronic devices for soldiers in the field, hikers and others whose physical motion could be harnessed and converted to electrical energy.

The February 14, 2008, issue of the journal *Nature* explained how pairs of textile fibers covered with zinc oxide nanowires can generate electrical current using the piezoelectric effect. Combining current flow from many fiber pairs woven into a shirt or jacket could allow the wearer's body movement to power a range of small electronic devices. The fibers could also be woven into curtains, tents or other structures to capture energy from wind motion, sound vibration or other mechanical energy.

"The fiber-based nanogenerator would be a simple and economical way to harvest energy from physical movement," says Zhong Lin Wang, a Regents' Professor in the School of Materials Science and Engineering at Georgia Tech. "If we can combine many of these fibers in double or triple layers in clothing, we could provide a flexible, foldable and wearable power source that, for example, would allow people to generate their own electrical current while walking."

The research was sponsored by the National Science Foundation (NSF), the U.S. Department of Energy and the Emory-Georgia Tech Nanotechnology Center for Personalized and Predictive Oncology.

The microfiber-nanowire hybrid system builds on the nanowire nanogenerator that Wang's research team announced in April 2007. That system generates current from arrays of vertically-aligned zinc oxide (ZnO) nanowires that flex beneath an electrode containing conductive platinum tips. The nanowire nanogenerator was designed to harness energy from environmental sources such as ultrasonic waves, mechanical vibrations or blood flow.

The nanogenerators developed by Wang's research group take advantage of the unique coupled piezoelectric and semiconducting properties of zinc oxide nanostructures, which produce small electrical charges when they are flexed. After a year of development, the original nanogenerators – which are two by three millimeters square – can produce up to 800 nanoamperes and 20 millivolts.

The microfiber nanogenerators rely on the same principles, but are made from soft materials and designed to capture energy from low-frequency motion. They consist of DuPont Kevlar® fibers on which zinc oxide nanowires have been grown radially and embedded in a polymer at their roots, creating what appear to be microscopic baby-bottle brushes with billions of bristles. One of the fibers in each pair is also coated with gold to serve as the electrode and to deflect the nanowire tips.

"The two fibers scrub together just like two bottle brushes with their bristles touching, and the piezoelectric-semiconductor process converts the mechanical motion into electrical energy," Wang explains. "Many of these devices could be put together to produce higher power output."

Wang and collaborators Xudong Wang and Yong Qin have measured current of about four nanoamperes and output voltage of about four millivolts from a nanogenerator of this type that included two fibers that were each one centimeter long. With a much-improved design, Wang estimates that a square meter of fabric made from the special fibers could theoretically generate as much as 80 milliwatts of power.

Fabrication of the microfiber nanogenerator begins with coating a 100-nanometer seed layer of zinc oxide onto the Kevlar using magnetron sputtering. The fibers are then immersed in a reactant solution for approximately 12 hours, which causes nanowires to grow from the seed layer at a temperature of 80 degrees Celsius. The growth produces uniform coverage of the fibers, with typical nanowire lengths of about 3.5 microns and several hundred nanometers between each fiber.

To help maintain the nanowires' connection to the Kevlar, the researchers apply two layers of tetraethoxysilane (TEOS) to the fiber.

Finally, the researchers apply a 300-nanometer layer of gold to some of the nanowire-covered Kevlar. The two different fibers are then paired up and entangled to ensure that a gold-coated fiber contacts a fiber covered only with zinc oxide nanowires. The gold fibers serve as a Shottky barrier with the zinc oxide, substituting for the platinum-tipped electrode used in the original nanogenerator.

By allowing nanowire growth to take place at temperatures as low as 80 degrees Celsius, the new fabrication technique would allow the nanostructures to be grown on virtually any shape or substrate.

As a next step, the researchers want to combine multiple fiber pairs to increase the current and voltage levels. They also plan to improve conductance of their fibers.

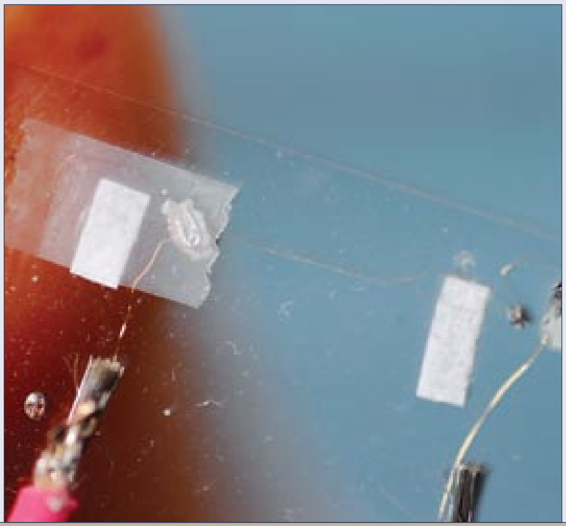
However, one significant challenge remains ahead for the power shirt – washing it. Zinc oxide is sensitive to moisture, so before the shirts or jackets could be commercially available, the nanowires would have to be protected from the effects of the washing machine, Wang notes. rh

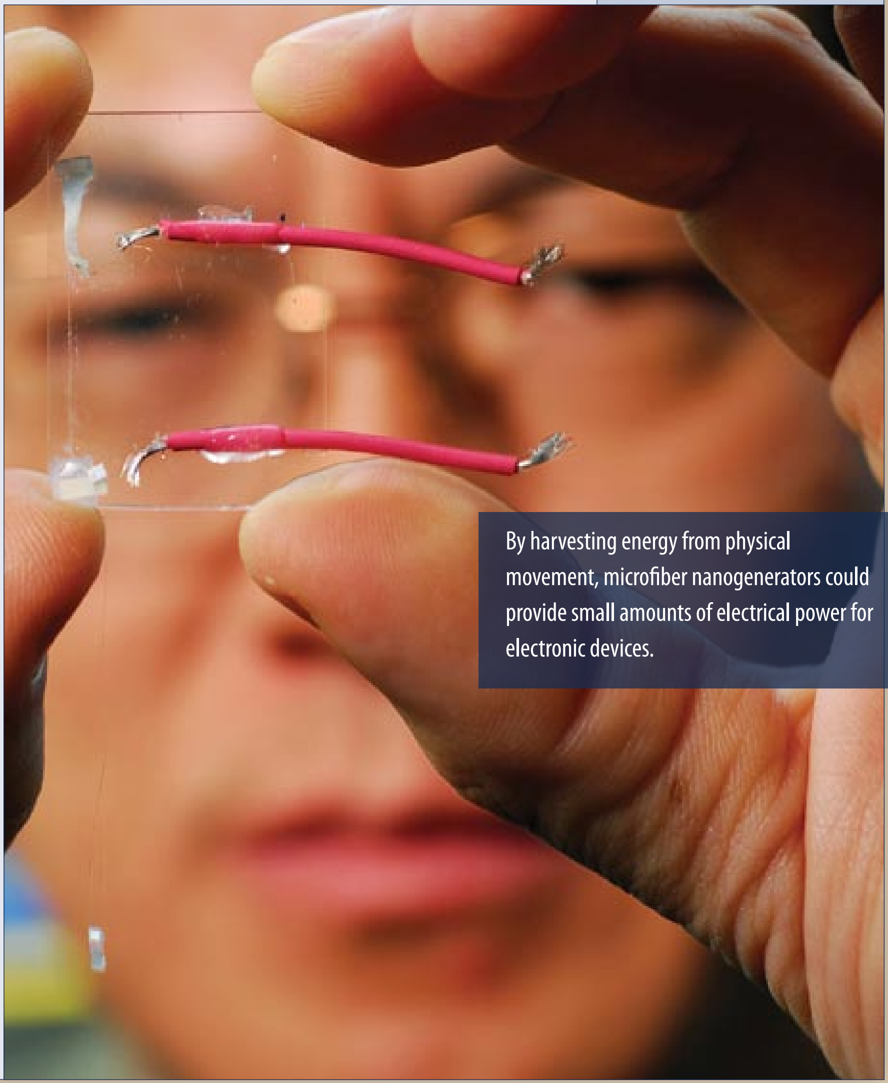
CONTACT

Zhong Lin Wang
404.894.8008
zhong.wang@mse.gatech.edu

"The fiber-based nanogenerator would be a simple and economical way to harvest energy from physical movement. If we can combine many of these fibers in double or triple layers in clothing, we could provide a flexible, foldable and wearable power source that, for example, would allow people to generate their own electrical current while walking."

- Zhong Lin Wang, Regents' Professor in the School of Materials Science and Engineering





By harvesting energy from physical movement, microfiber nanogenerators could provide small amounts of electrical power for electronic devices.