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Small in Scale, Big in Possibilities: Wayne State Researcher Develops Nano- and Micro-Scale Devices for Improved Medical Practices

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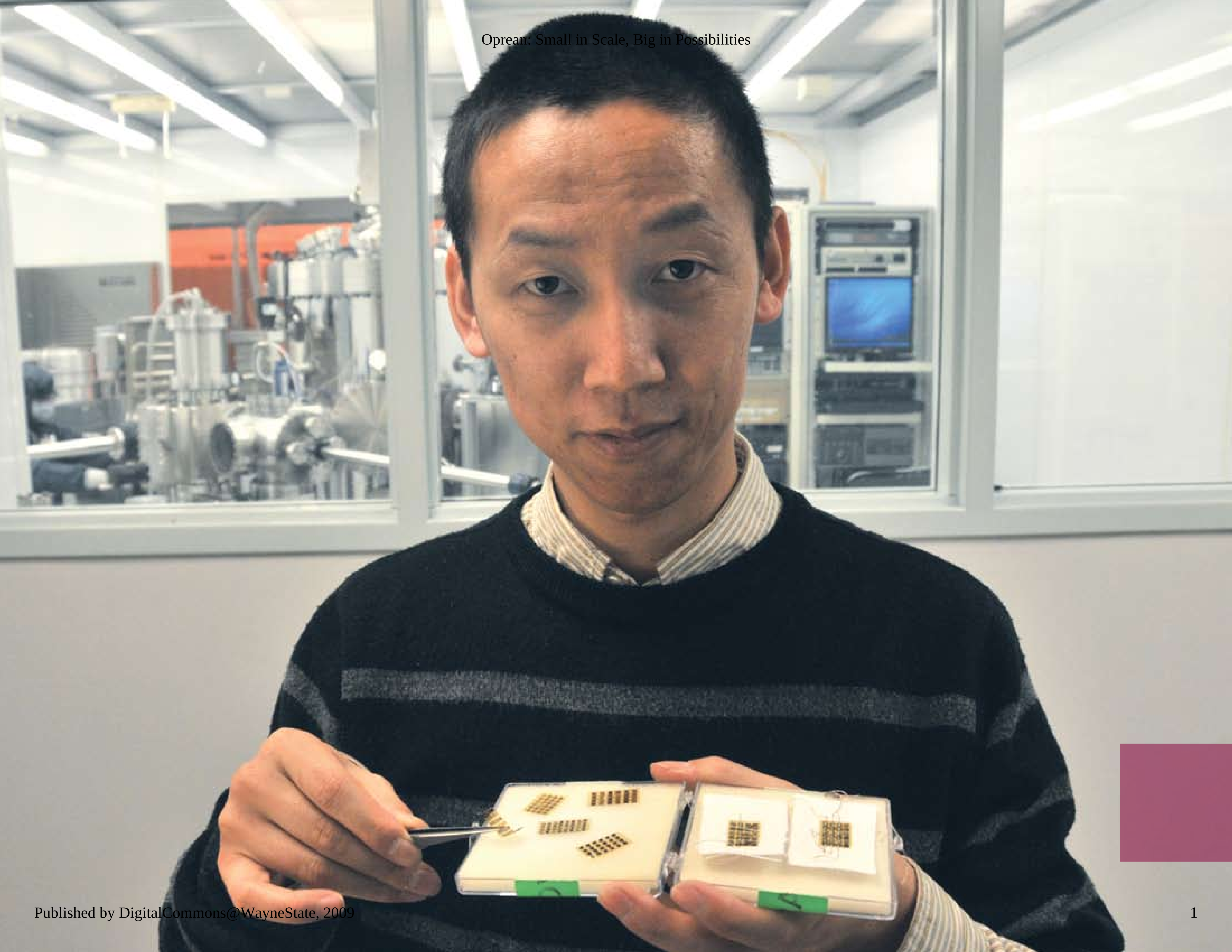

Small in Scale, Big in Possibilities

Wayne State researcher develops nano- and micro-scale devices for improved medical practices

by Amy Oprean

The stethoscope is a longstanding symbol of the medical profession, having been used by doctors for more than two centuries to obtain basic vital signs through listening to the heart and respiratory noises. Although it is a fundamental part of almost every medical exam and surgical procedure, stethoscopes have several major disadvantages. Among these is the inability to give continuous readings and a bulky size that prevents their use in some situations.

Yong Xu, Ph.D., associate professor of electrical and computer engineering in the College of Engineering, received a National Science Foundation CAREER award, a prestigious award given to promising faculty early in their career, to develop a stethoscope alternative that has the potential to change the paradigm for respiratory sound monitoring. Using a micro-scale cantilever design and intelligent textile technology, Xu is developing a micro-sensor that is sensitive and compact; capable of picking up the weak vibrations given off by breathing, yet small enough to be worn comfortably throughout the day for continuous monitoring.

> "This polymer skin can be stitched into fabric or made into a bandage, allowing the sensor to be applied to the patient very conveniently."
>
> **— Dr. Yong Xu**

One of the major disadvantages of stethoscopes is that they cannot be used for continuous respiratory sound monitoring. For example, during surgery, readings are taken only intermittently. And because of their size, stethoscopes cannot be applied to obstructed locations, such as the side of the body a person is lying on during surgery.

An accelerometer, an electromechanical device that measures acceleration forces, could be a feasible alternative sound monitoring device, Xu said, as long as it is designed with both sensitivity and comfort in mind. He has proposed two novel approaches to address these requirements, the first being an air-spaced cantilever design for the accelerometer. Easily observed in two inch by three-quarter inch metal macro version, Xu's cantilever design consists of a flat rectangular metal base with a rectangle-shaped depression in the middle. A flat, thinner piece of piezoelectric material sits on top of the base, creating a bridge over the depression from which a vibration will be made. Though other accelerometers have been designed with respiratory noise monitoring in mind, the geometry of Xu's design has been optimized for maximum sensitivity.

Xu is now working to micro-fabricate the macro version of this device, the end result being a two millimeter by two millimeter silicon sensor. Using intelligent textile technology, Xu will fashion these micro sensors on a flexible polymer skin, allowing the device to bend with a patient's movement. "This polymer skin can be stitched into fabric or made into a bandage, allowing the sensor to be applied to the patient very conveniently," he said. "The key is to keep it very small and lightweight, because patients would have problems wearing a heavy device for 20-plus hours a day."

Dr. Yong Xu, associate professor of electrical and computer engineering

Small in Scale, Big in Possibilities continued

The need for this type of continuous respiratory sound monitoring is apparent in several areas of medicine, and could result in an improved paradigm in monitoring respiration of patients under anesthesia, asthma management, patient monitoring in intensive care units, nursing facilities, emergency medical services and sleep studies. There is also the potential application for non-invasive vital sign monitoring for pilots and other military personnel, for which there is no method of continuous respiratory sound tracking.

Xu is collaborating with Hong Wang, M.D., Ph.D., associate professor of anesthesiology in WSU's School of Medicine, on the medical aspects of the research, and Le Yi Wang, Ph.D., professor of electrical and computer engineering in WSU's College of Engineering, to develop signal processing for the device. Once completed, the sensor will be tested using a human simulator at Harper Hospital in Detroit, as well as on humans. "Ultimately, it will be tested on humans to see if we can detect a useful signal," he said. "We'll do that by testing it against a state-of-the-art stethoscope, to see how the components of this device compare with the stethoscope."

Xu is also working on another type of cantilever with a completely different application. Funded by WSU's Presidential Research Enhancement Program, he has spent two years developing a piezoresistive cantilever for biochemical sensing.

Biochemical sensors allow scientists to perform tasks such as reading DNA sequences, an essential part of disease diagnoses. They also play crucial roles in drug discovery, national security, environmental monitoring and food safety.

Scientists measure biochemicals by immersing nanoscale cantilevers in the substance of interest and measuring the biomolecules that move over their surfaces. The most popular technique used is the optical lever method, in which the change in a cantilever's surface stress is measured by reflecting a laser off its surface and measuring the displacement with photo sensors. However, the method has several disadvantages in that it's bulky, expensive, not easily portable and difficult to use when monitoring a large number of cantilevers.

"The problem with this is that you need a laser and a photo sensor, which is expensive," Xu said. "Also, it cannot be miniaturized, and it's difficult to monitor a large number of cantilevers simultaneously. If you have one cantilever, it's no problem, but for ten cantilevers, you would need ten lasers. That's not easy to do."

The piezoresistive method, by contrast, uses electricity to measure changes in the cantilever's resistance. However, because of their relatively low sensitivity, piezoresistive cantilevers are still inferior to optical cantilevers. Xu is working to develop a more sensitive piezoresistive cantilever using two novel approaches. The first is to use parylene, a family of thermoplastic polymers as the cantilever material. The second innovation is to increase the surface area of the cantilever using nanoparticles.

A cantilever of this size would be an ideal solution for producing a high volume, low cost portable device that can be rapidly deployed. The improved piezoresistive cantilever method will have a large number of diverse biochemical sensing applications such as detection of mercury vapors, explosives, hydrogen gases, volatile organic solvents, heavy metals, DNA hybridization, DNA-RNA binding, antigen-antibody binding and protein ligand binding. These applications will play significant roles in increasing protection in war zones, making the environment cleaner and lowering medical costs, ultimately impacting the lives of many.

About Dr. Yong Xu: Dr. Xu received a B.S. in electronic engineering from Tsinghua University in Beijing, China. He received an M.S. and a Ph.D. in electrical engineering from the California Institute of Technology. His research interests include smart skins based on micro-electro-mechanical system, intelligent textiles, microfluidics, biosensors, medical devices, neural interfaces, energy harvesting and nanotechnology. He joined Wayne State in 2002.