Team invents sensor that uses radio waves to detect subtle changes in pressure

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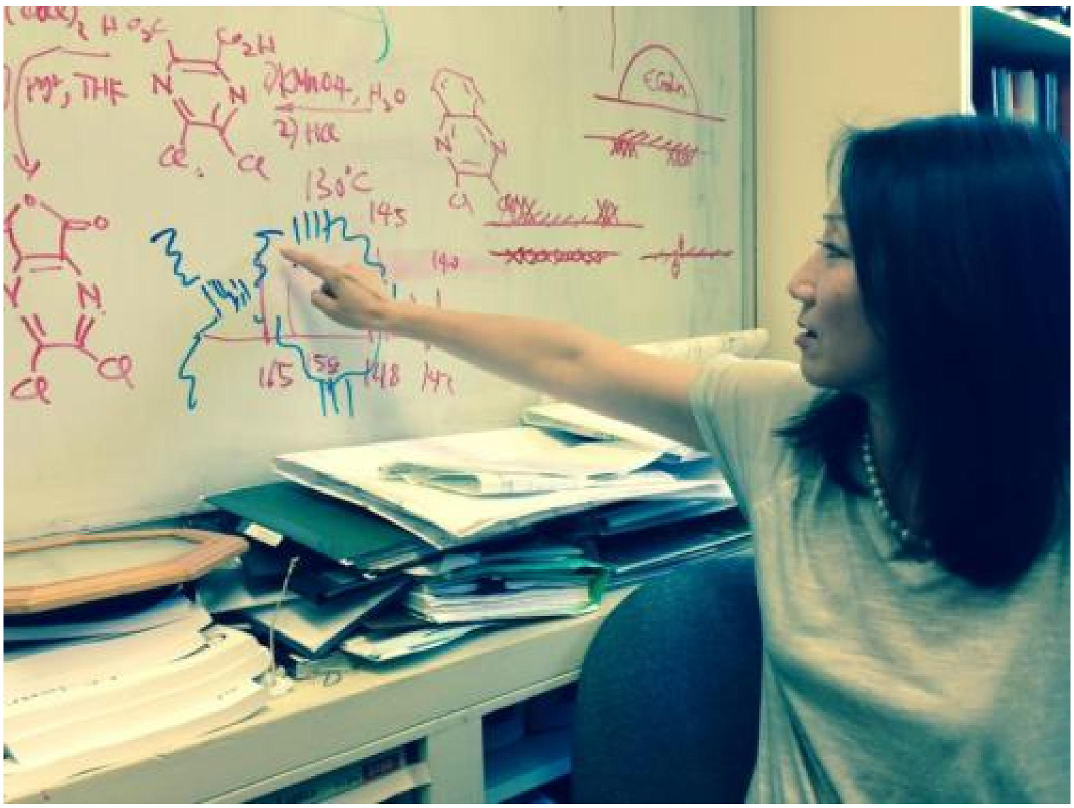

Stanford Chemical Engineering Professor Zhenan Bao points to a diagram of a rubber molecule, indicating the springy feature exploited by her team's wireless pressure sensor. Credit: Stanford Engineering

Stanford engineers have invented a wireless pressure sensor that has already been used to measure brain pressure in lab mice with brain injuries.

The underlying technology has such broad potential that it could one day be used to create skin-like materials that can sense pressure, leading to prosthetic devices with the electronic equivalent of a sense of touch.

A nine-member research team led by Chemical Engineering Professor Zhenan Bao detailed two medical applications of this technology in *Nature Communications*.

In one simple demonstration they used this wireless pressure sensor to read a team member's pulse without touching him.

In a more complex application, they used this wireless device to monitor the pressure inside the skull of a lab mouse, an achievement that could one day lead to better ways to treat human brain injuries.

Bao's wireless sensor is made by placing a thin layer of specially designed rubber between two strips of copper. The copper strips act like radio antennas. The rubber serves as an insulator.

The technology involves beaming radio waves through this simple antenna-and-rubber sandwich. When the device comes under pressure, the copper antennas squeeze the rubber insulator and move infinitesimally closer together.

That tiny change in proximity alters the electrical characteristics of the device. Radio waves passing through the two antennas slow down in terms of frequency. When pressure is relaxed, the copper antennas move apart and the radio waves accelerate in frequency.

The engineers proved that this effect was measurable, giving them a way to gauge the pressure exerted on the device by tracking the frequency of radio waves passing through the device.

Former Stanford graduate students Lisa Chen and Benjamin C-K Tee designed and modeled the physics behind the device, and calibrated the pressure sensor in simple laboratory tests. Alex Chortos, graduate student in the department of materials science and engineering, made the wireless device more robust and re-usable.

When the engineers sought collaborators to test the device in potentially useful applications, H.–S. Philip Wong, a professor of electrical engineering, connected them with Victor Tse, a neurosurgeon and consulting associate professor at Stanford School of Medicine.

Tse tested the wireless pressure sensor as a tool for managing patients with severe brain trauma. The most devastating problem in such cases is brain swelling. Currently, physicians diagnose brain swelling with imaging techniques such as CT scans or by monitoring intracranial pressure (ICP) directly.

ICP monitoring is traditionally done using probes that penetrate the skull and are linked to an external monitor via a cable. In addition to the possibility of the cable being pulled out or dislodged, this cumbersome solution carries the risk of infection. Measuring ICP using cables become particularly challenging when patients are moved within the hospital or transported to other facilities.

In experiments on laboratory mice, Tse used radio waves to probe Bao's wireless sensor, allowing him to monitor changes in intracranial pressure continuously.

"Our team is now considering how to incorporate this device into a catheter that could siphon out cerebral spinal fluid whenever there is an increase in ICP," Tse said. On a slightly different tack, his team is thinking about how to retool the wireless sensor so that it could be placed in the eye socket. There it could be used to measure pressure in the eye socket, a relatively easy-to-obtain surrogate for tracking intracranial pressure on the brain.

In a separate effort, Dr. Michael McConnell, a professor of cardiovascular medicine, used the device to take a wireless pulse reading as a proof of principle that the technology could be applied to pressures having to do with blood circulation.

For Bao, this is the latest in a series of experiments that capitalize on a simple but far-reaching advance that her lab made several years ago. That advance has to do with the design of the rubber layer used in this device.

As Bao explained, rubber is special because its basic molecular structure can compress and spring back into shape. Other materials simply don't have this spring-like feature. Simple as it may seem, her lab discovered that creating a pyramid-shaped layer of rubber instead of a flat mat gave the individual rubber molecules more freedom to flatten out and then spring back into shape.

By putting this pyramid-shaped rubber layer between the copper antennas, this team of engineers was able to exploit the subtle interactions of radio waves and electron clouds to create a pressure gauge.

Bao foresees many potential applications for this pressure-sensing technology.

"The device we invented here is extremely easy to manufacture and consumes no energy until readings are being made," she said. "In the short term we hope to use devices like this to track packages and monitor health conditions. In the longer run we dream of using this technology to create touch-sensitive lining for prosthetic devices."

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