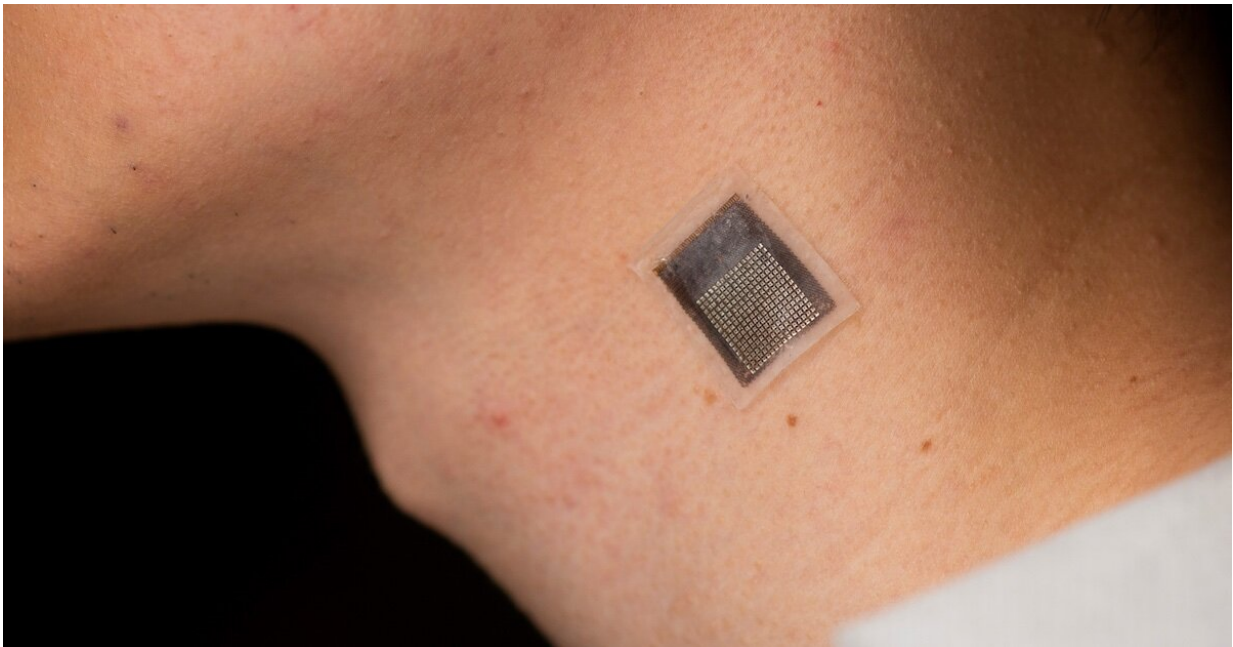


# Wearable ultrasound patch provide non-invasive deep tissue monitoring

May 3 2023, by Emerson Dameron

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Ultrasound patch worn on the neck. Credit: UC San Diego Jacobs School of Engineering

A team of engineers at the University of California San Diego has developed a stretchable ultrasonic array capable of serial, non-invasive, three-dimensional imaging of tissues as deep as four centimeters below the surface of human skin, at a spatial resolution of 0.5 millimeters. This new method provides a non-invasive, longer-term alternative to current methods, with improved penetration depth.

The research emerges from the lab of Sheng Xu, a professor of nanoengineering at UC San Diego Jacobs School of Engineering and corresponding author of the study. The paper, "Stretchable ultrasonic arrays for the three-dimensional mapping of the modulus of deep tissue," was published in the May 1, 2023, issue of *Nature Biomedical Engineering*.

"We invented a [wearable device](#) that can frequently evaluate the stiffness of human tissue," said Hongjie Hu, a postdoctoral researcher in the Xu group and study co-author. "In particular, we integrated an array of ultrasound elements into a soft elastomer matrix and used wavy serpentine stretchable electrodes to connect these elements, enabling the device to conform to [human skin](#) for serial assessment of tissue stiffness."

The elastography monitoring system can provide serial, non-invasive and three-dimensional mapping of mechanical properties for deep tissues. This has several key applications:

- In [medical research](#), serial data on pathological tissues can provide crucial information on the progression of diseases such as cancer, which normally causes cells to stiffen.
- Monitoring muscles, tendons and ligaments can help diagnose and treat sports injuries.
- Current treatments for liver and cardiovascular illnesses, along with some chemotherapy agents, may affect tissue stiffness. Continuous elastography could help assess the efficacy and delivery of these medications. This might aid in creating novel treatments.

In addition to monitoring cancerous tissues, this technology can also be applied in other scenarios:

- Monitoring of fibrosis and cirrhosis of the liver. By using this technology to evaluate the severity of liver fibrosis, [medical professionals](#) can accurately track the progression of the disease and determine the most appropriate course of treatment.
- Assessing musculoskeletal disorders such as tendonitis, tennis elbow and carpal tunnel syndrome. By monitoring changes in tissue stiffness, this technology can provide valuable insight into the progression of these conditions, allowing doctors to develop individualized treatment plans for their patients.
- Diagnosis and monitoring for myocardial ischemia. By monitoring arterial wall elasticity, doctors can identify early signs of the condition and make timely interventions to prevent further damage.

Wearable ultrasound patches accomplish the detection function of traditional ultrasound and also break through the limitations of traditional ultrasound technology, such as one-time testing, testing only within hospitals and the need for staff operation.

"This allows patients to continuously monitor their health status anytime, anywhere," said Hu.

This could help reduce misdiagnoses and fatalities, as well as significantly cutting costs by providing a non-invasive and low-cost alternative to traditional diagnostic procedures.

"This new wave of wearable ultrasound technology is driving a transformation in the healthcare monitoring field, improving patient outcomes, reducing healthcare costs and promoting the widespread adoption of point-of-care diagnosis," said Yuxiang Ma, a visiting student in the Xu group and study co-author. "As this technology continues to develop, it is likely that we will see even more significant advances in the field of medical imaging and healthcare monitoring."

The array conforms to human skin and acoustically couples with it, allowing for accurate elastographic imaging validated with magnetic resonance elastography.

In testing, the device was used to map three-dimensional distributions of the Young's modulus of tissues *ex vivo*, to detect microstructural damage in the muscles of volunteers prior to the onset of soreness and monitor the dynamic recovery process of muscle injuries during physiotherapy.

The device consists of a 16 by 16 array. Each element is composed of a 1-3 composite element and a backing layer made from a silver-epoxy composite designed to absorb excessive vibration, broadening the bandwidth and improving axial resolution.

Such technology must record the motion of scattering particles in the sample by ultrasound wave and calculate their displacement fields based on a normalized cross-correlation algorithm. The size of scattering particles is very small, resulting in the weak reflected signals. To capture such faint signals requires acutely sensitive technology.

Existing fabrication methods involve high-temperature bonding that can cause serious, irreversible thermal damage to the epoxy in the piezoelectric materials. As a result, the sensitivity of the transducer element degrades significantly.

"To address those challenges, we developed a low-temperature bonding approach," said Hu. "We replaced the solder paste with conductive epoxy, which allows the bonding to be completed at room temperature without causing any damage to the element. In addition, we replaced the single plane wave transmission mode with coherent plane-wave compounding mode, which provides more energy to boost the signal intensity throughout the entire sample. Using these strategies, we improve the sensitivity of the device to make it perform well in

capturing those weak signals from scattering particles."

"A layer of elastomer with known modulus, the so-called calibration layer, can be installed on our device to further obtain quantitative, absolute values of tissues' moduli," said Dawei Song, a postdoctoral researcher at the University of Pennsylvania and study co-author. "This approach would allow us to obtain more complete information about tissues' mechanical properties, thus further improving the diagnostic capabilities of the ultrasonic devices."

Additionally, advanced lithography, pick-and-place and dicing techniques can be adopted to further optimize the array design and fabrication, which can reduce the pitch and extend the aperture to achieve a higher spatial resolution and a broader sonographic window.

"It would be easier to explore opportunities working with physicians, pursuing potential practical applications in clinics," said Gao. "Our device shows great potential in close [monitoring](#) of high-risk groups, enabling timely interventions at urgent moments," said Gao.

**More information:** Hongjie Hu et al, Stretchable ultrasonic arrays for the three-dimensional mapping of the modulus of deep tissue, *Nature Biomedical Engineering* (2023). [DOI: 10.1038/s41551-023-01038-w](https://doi.org/10.1038/s41551-023-01038-w)

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