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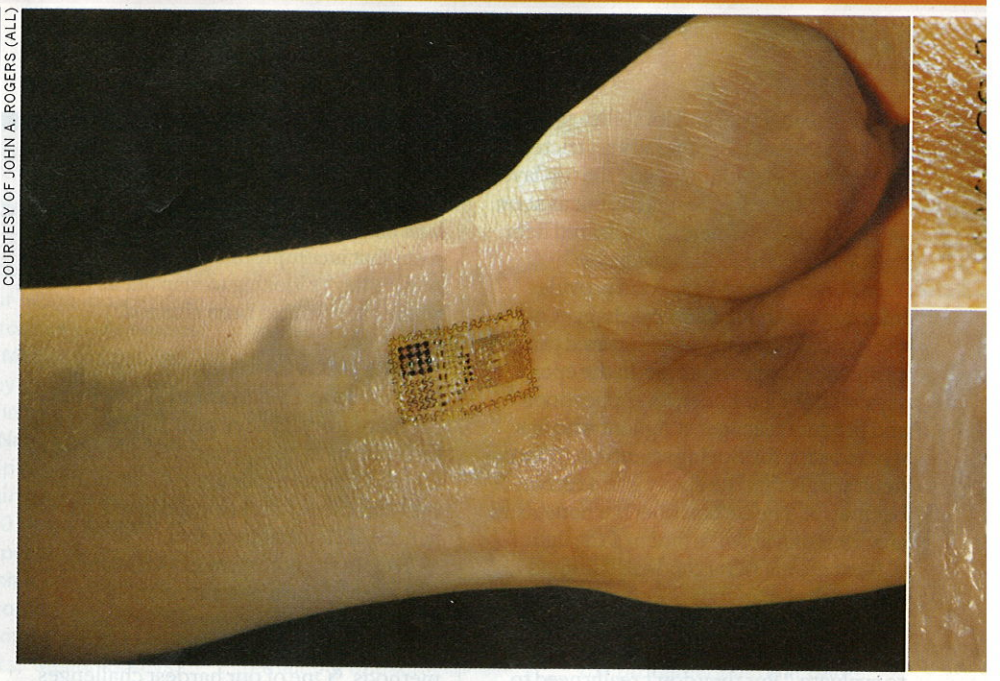


COURTESY OF JOHN A. ROGERS (ALL)

ELECTRONIC SKIN

Ultrathin devices **CLING TO SKIN** like temporary tattoos

BETHANY HALFORD, C&EN NORTHEAST NEWS BUREAU

PEOPLE DON'T have electrical outlets on their bodies. So establishing a connection between humans and electronics, such as a heart monitor, typically requires strapping, taping, or clamping electrodes onto the skin and then hooking them up to machines. It's enough to make even a healthy person's heart race.

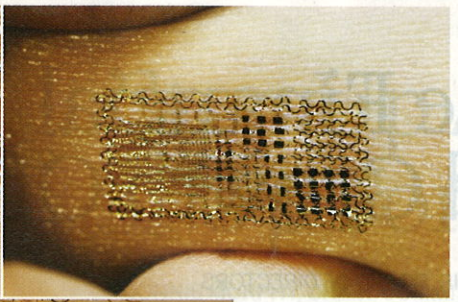
Now, thanks to a new electronic system that clings to skin, gathering data from the human body could be as simple as sticking on a temporary tattoo. A team led by John A. Rogers, a materials science professor at the University of Illinois, Urbana-Champaign, developed so-called epidermal electronics, which they recently reported in a paper in *Science* (DOI: 10.1126/science.1206157). The postage-stamp-sized devices adhere to the skin via van der Waals interactions alone and are whisper thin at just 37 μm—roughly the thickness of a human hair.

"The skin is a particularly interesting point of integration," Rogers says. "Skin is the largest organ. It provides our main point of nonvisual sensory interaction with the outside world, and it is a place where people have attempted to interface electrodes and electronics for decades."

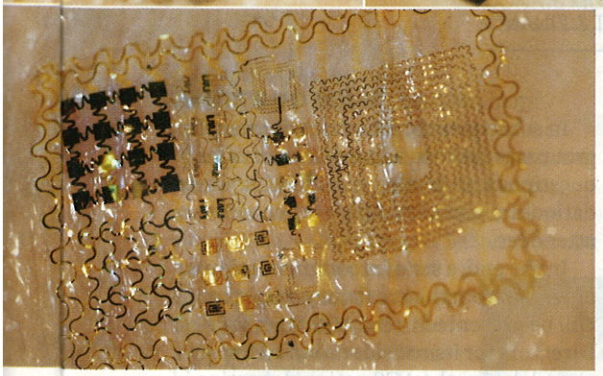
The main hurdle in creating such interfaces is getting electronic components, which are typically rigid and hard, to stick to and move with soft, pliable skin, with its uneven features. "We're trying to reshape electronics to look like the human body, in this case, the surface layers of the skin," Rogers says. "The goal was to blur the distinction between electronics and biological tissues."

To accomplish this, Rogers' team fashioned the devices' active components out of silicon and gallium arsenide nanomembranes that were formed into filaments with a serpentine shape. These were connected to similarly serpentine-shaped wires, resulting in what Rogers describes as a "spider web mesh of electronics" that can move with the skin. The components were applied to a flexible elastomer to create an assembly that's about as thick as human skin. The entire setup was then mounted onto a polymer backing sheet that keeps

"The goal was to blur the distinction between electronics and biological tissues."



HIGH-TECH TATTOO Epidermal electronics adhere intimately to the skin, clinging to its wrinkles and puckers even when skin is stretched, compressed, or poked.



the malleable system stiff enough to handle—an idea Rogers says he got from temporary tattoos.

Attaching the devices is as simple as pressing one onto the area of skin to be interfaced with and then washing off the polymer backing. The wearer can barely feel the device, Rogers says, and it will stay on the skin for about two weeks before there's any irritation.

The researchers even demonstrate that a temporary tattoo can substitute for the polymer backing sheet and provide camouflage for the shiny electronic components. It's the perfect disguise if one wanted to use the electronic skin for cloak-and-dagger applications such as covert communications.

Stéphanie Lacour, a flexible-electronics expert at the Swiss Federal Polytechnic Institute of Lausanne, calls the work "a very nice demonstration of truly skinlike electronics." She notes that the integration of high-performance circuitry on such a soft substrate as the flexible elastomer—with an elastic modulus, or bendability, of tens of kilopascals—is particularly impressive. "It is worth noting that microelectronics are usually prepared on stiff substrates of gigapascal-range moduli," she says.

"As an engineer working on soft bioelectronics interfaces, I believe this paper is a key demonstration that high-performance electronics can be designed to closely mimic biological tissues and yet function reliably," Lacour adds.

Rogers' team envisions myriad applications for the electronics, including neonatal and sleep apnea monitoring, as well as prosthetic control systems. They've incorporated electrophysiological, temperature, and strain sensors into the devices, as well as light-emitting diodes, transistors, radio frequency capacitors, wireless antennas, and conductive coils and solar cells for power. "We threw everything in our bag of tricks onto that platform, and then added a few other new ideas on top of those, to show that we could make it work," he says.

IN THE PAPER, the researchers demonstrate that the device can be used to measure electrical activity from the brain, heart, and skeletal muscles. They even applied a patch of electronic skin to a man's throat and interfaced it with video game software, demonstrating that the man could control the video game "Sokoban," where a player pushes boxes around a warehouse, by simply saying "up," "down," "right," and "left." The electronic skin detects the difference in muscle movement for each word, and the software translates those differences into commands for the video game.

Rogers also says they've incorporated all the components they'd need to turn the device into a radio; they just have to hook them up into a working system. The devices are being developed for commercialization by mc10, a Cambridge, Mass.-based start-up company Rogers founded with Harvard University chemistry professor George M. Whitesides. The firm already has a joint development agreement with Reebok to create sportswear with this type of technology, Rogers says.

Rogers sees his next steps as an academic researcher delving further into the realm of biochemical electronics. "The future for us is to figure out ways for these devices to interact with the tissue using the currency of biology—proteins, enzymes, and other biomolecules—rather than just through electrons and photons," he tells C&EN. "Chemistry has a huge role to play in this space." ■

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