Electronic skin

By Stephen Ornes / January 18, 2012

James Bond and his enemies would be interested in the goings-on at the laboratory of John Rogers. So would Batman, the Spy Kids, Darth Vader and their enemies. That's because Rogers, a materials scientist at the University of Illinois at Urbana-Champaign, mixes electronics with the human body to create new devices not found even in science fiction.

Make room, Lord Vader. There's a new kind of cyborg in town.

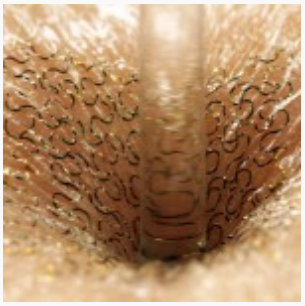
Rogers and his collaborators have built an electronic device that's smaller than a postage stamp and sticks to the skin like a temporary tattoo. The device's possible users — patients, athletes, doctors, secret agents, you — are limited only by their imaginations.

This isn't an ordinary temporary tattoo. This transparent device can measure a wearer's blood flow, muscle movement, electrical signals — and wirelessly send that information to a computer. Credit: Image courtesy of John A. Rogers

Placed on a forehead, the device can record brainwaves; on the wrist, blood flow and muscle movement. On the skin of sick patients, it can track vital signs and watch for problems, replacing the bulky equipment usually found in hospitals. And stuck to the throat, it can function as a secret cell phone, activated by the movements of a person's voice box.

The scientists designed the device, about half as thick as an ordinary sheet of paper, with skin in mind. Like skin, the electronic material can be stretched and squashed in many ways but keep on working.

Scientists who design devices for the body have to study how it functions, down to a tiny, cellular level. The body and the machine have to speak the same language. "We wanted to build devices that interact with the body," Rogers says.



These skin-stuck devices mimic the properties of skin, which means they can stand up to poking, stretching and squeezing. Credit: Image courtesy John A. Rogers

Last fall, Rogers and his colleagues demonstrated how their new device measures the body in different ways. The invention can record temperature, muscle motion or the electrical activity on a person's skin. It may be outfitted with lights and a tiny power source, which means it can wirelessly transmit data to a nearby computer. This device may even change the way we think about medical tools and how doctors help their patients, inside and out.

Tattoos you can use

Rogers doesn't have any permanent tattoos. But he says he's been wearing "more and more" of the temporary kind to hide the stuck-on electronic circuits. (He even concealed one device behind a blue pirate tattoo.) Temporary tattoos use a simple and inexpensive way to adhere, or stick, to skin: a good sticky backing that stretches and flexes with skin's natural motion.

Rogers and his colleagues have been experimenting with their new devices in the lab, taking various measurements of and from different parts of the body.

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"We've done extensive testing," says Todd Coleman, an engineer who tackles the problem of getting the device, the body and the mind to "talk" to each other. "I put one [device] near my forearm and clenched my fist to see how it monitored my muscle signals and movements. If you put it on the surface of the head, it records brain waves. Near the heart, it picks up heartbeat information. It's the same device, just in different places."

Skin-based, or epidermal, electronic systems stick to the skin like temporary tattoos. Attached to the head, they can pick up electrical signals from the brain. Credit: Image courtesy John A. Rogers

The device is so light that a wearer may forget it's there, says Coleman, now at the University of California San Diego. "We were trying to develop a piece of electronic material that is also basically completely invisible to the user. You barely even feel that the device is on your body," he says.

More than skin deep

The scientists have found a way to extend the technology deeper than the body's surface. In 2010, they introduced an electrical plastic wrap that can be attached to a person's heart during open-heart surgery. Electronic circuits and instruments record blood flow and electric current, which means the material can alert doctors to hidden problems with a patient's ticker. The team has already shown that a device attached to the surface of the brain can capture the electrical signals of an epileptic seizure.

Rogers, who says he's always been drawn to science, regularly participated in science fairs as a kid. But as he got older, he realized that scientists' work can create positive changes in the world.

"Making devices that have real benefits to society has been a real focus of our team, especially in recent years," he says. "We are aiming to create devices that bring new ways to address health problems and other grand challenges in society."

Spies and deep-sea divers might also take note of the new "skintronics": Attached to the neck, for example, the devices could detect the throat movements of speaking. That means a person can mouth words — without making a peep — and the device would record the movements and relay the silent message. It would be perfect for covert operations.

An electroencephalograph, or EEG, detects and measures electrical signals from the brain. But the device, which requires a lot of wires and time, is ready for an upgrade. Credit: istockphoto

"It's unbelievable how much fun we've had having conversations with others about the device," Coleman says.

Silicon: The problem and the answer

Scientists have been attaching electrical gadgets to skin for more than 80 years. In 1929, a German doctor named Hans Berger invented a device that attaches to the scalp and measures the brain's electrical activity. His invention, called an electroencephalograph (EEG), lets doctors "read" brain activity. An EEG can help doctors diagnose diseases like epilepsy or detect when a patient slips into a coma.

But the EEG has a major drawback: It's clunky. Technicians tape a complex web of small nodes and wires to the head to get a good read. And EEG's need power, delivered through wires, which adds to the mess. That's not just a problem for EEG's; it's a problem for almost every electrical device, even fictional bits of gadgetry used by Batman or James Bond.

A lighter, bendable device would provide the same information as an EEG, but without the heft. That idea started to seem like a reality in the early 1990s, when scientists around the world were racing to create flexible electronics. Computers became popular during this time, but most looked like clunky boxes attached to a nest of wires. Researchers envisioned flexible screens and computing devices that would bend and fold

like paper.

Rogers wanted to go even further.

“I thought a more challenging goal might be to make an electronic device that bends like a sheet of paper but stretches like a rubber band,” he says.

A problem loomed. Computers depend on an element called silicon. In nature, silicon appears as a dark-gray crystal. Thin wafers of the material conduct electricity, and for decades silicon has been used to make computer chips and other electronic parts. Silicon is important, useful stuff. But silicon wafers are brittle, which means they break easily.

Rogers and his colleagues thought silicon perhaps could be made to bend like skin and not shatter. There wasn’t much they could do to the silicon material itself. But they thought arranging silicon wires into just the right shape might give the material more flexibility.

The scientists wanted silicon to expand like an accordion’s bellows, the part of the instrument that looks like a folded rubber sheet. When a person plays the accordion, the bellows unfold and move farther apart from each other without the material itself stretching. Rogers wanted to take a similar approach, designing the device so its wires could “unfold” — letting the silicon strands move — without shattering.

An accordion player widens and narrows the instrument’s bellows (red in photo) to control the flow of air. Like bellows, electronic skin devices have a shape that allows material to compress and expand without breaking. Credit: Palmkvist Knudsen/Wikimedia

After three years of building and experimenting, Coleman says, the researchers produced a working device. Up close, the silicon looks like tiny, twisty snakes that wind through the material in complicated patterns. These winding silicon shapes form the different parts of the device — the sensors, antennae and power supply — and they can withstand stretching, poking and squeezing.

Mixing bodies and machines

In the not-so-distant future, surgery patients may find themselves wearing smart temporary tattoos, rather than bulky devices covered with wires. Rogers’ work is part of the growing field of “biointegrated technology,” devices built with the body in mind. They bring together machines and living things to improve lives. In the future, Rogers wants to extend the technology to create tiny devices that may even be able to operate independently within the body, improving, for example, the health of the human heart.

“The most immediate opportunity for biointegrated technology is to redefine what a surgical tool is,” he says. “My hope is that [the devices] will really have a large impact on the way that people think about surgical operations.” The ultimate goal, he says, is for the devices to track body and brain activity and “eliminate the need for surgical interventions in the first place.”

With his research group in San Diego, Coleman wants to create new ways for people to use their brains to talk to machines — or even each other. He imagines a world in which people can work together, or even think together, using the devices to transmit information directly from their minds. “You could interact with a friend in both the natural and virtual world, using not only your behavior but also your thoughts,” he says.

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The idea of connecting brains with the devices has implications in the classroom, too. “If we can monitor the brain signals between teachers and students who are interacting, then maybe we can learn the extent to which they understand each other,” Coleman says. “That could revolutionize education and training. It’s easy to imagine the possibilities. And if we don’t imagine, then what are we doing?”

Tiny snakelike strands of silicon are key to electronic skin devices’ success, allowing them to be flexible like skin. Credit: Image courtesy of John A. Rogers

POWER WORDS (adapted from the New Oxford American Dictionary and acs.org)

materials science The study of how a material’s structure is related to its properties.

electroencephalography The measurement of electrical activity in different parts of the brain and the recording of such activity as a visual trace.

epidermis The outer layer of skin.

silicon A nonmetal, semiconducting element used in making electronic circuits. Pure silicon exists in a shiny dark-gray crystalline form and as a shapeless powder.