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Implantable Silicon-Silk Electronics

Biodegradable circuits could enable better neural interfaces and LED tattoos.

By Katherine Bourzac TUESDAY, NOVEMBER 03, 2009

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By building thin, flexible silicon electronics on silk substrates, researchers have made electronics that almost completely dissolve inside the body. So far the research group has demonstrated arrays of transistors made on thin films of silk. While electronics must usually be encased to protect them from the body, these electronics don't need protection, and the silk means the electronics conform to biological tissue. The silk melts away over time and the thin silicon circuits left behind don't cause irritation because they are just nanometers thick.

Silicon on silk: This clear silk film, about one centimeter squared, has six silicon transistors on its surface. These flexible devices can be implanted in mice like the one in this image without causing any harm, and the silk degrades over time. The orange liquid on the hair is a disinfectant used during the surgery. Credit: Rogers/Omenetto

"Current medical devices are very limited by the fact that the active electronics have to be 'canned,' or isolated from the body, and are on rigid silicon," says Brian Litt, associate professor of neurology and bioengineering at the University of Pennsylvania. Litt, who is working with the silk-silicon group to develop medical applications for the new devices, says they could interact with tissues in new ways. The group is developing silk-silicon LEDs that might act as photonic tattoos that can show blood-sugar readings, as well as arrays of conformable electrodes that might interface with the nervous system.

Last year, John Rogers, professor of materials science and engineering at the Beckman Institute at the University of Illinois at Champaign-Urbana, developed flexible, stretchable silicon circuits whose performance matches that of their rigid counterparts. To make these devices biocompatible, Rogers's lab collaborated with Fiorenzo Omenetto and David Kaplan, professors of bioengineering at Tufts University in Medford, MA, who last year reported making nanopatterned optical devices from silkworm-cocoon proteins.

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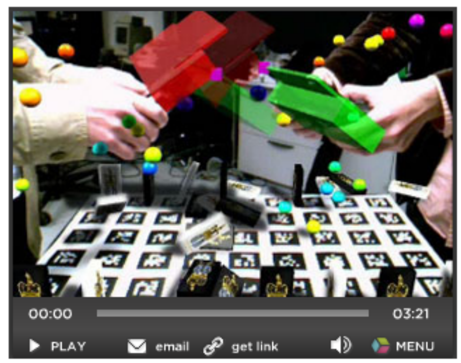

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To make the devices, silicon transistors about one millimeter long and 250 nanometers thick are collected on a stamp and then transferred to the surface of a thin film of silk. The silk holds each device in place, even after the array is implanted in an animal and wetted with saline, causing it to conform to the tissue surface. In a paper published in the journal Applied Physics Letters, the researchers report that these devices can be implanted in animals with no adverse effects. And the performance of the transistors on silk inside the body doesn't suffer.

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In the silk-silicon electronics, the silk plays a passive but important role. "Silk is mechanically strong enough to act as a support, but if you pour water on it, it conforms to the tissue surface," says Omenetto. Silk is already approved by the U.S. Food and Drug Administration for medical implants and is broken down completely by the body into harmless by-products. The silk sheets are flexible, and can be rolled up and then unfurled during surgery, making them easier for surgeons to work with. By adjusting the processing conditions used to fabricate the films, the Tufts researchers can control the rate at which the films will degrade, from immediately after implantation to years.

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The biocompatibility of silicon is not as well established as that of silk, though all studies so far have shown the material to be safe. It seems to depend on the size and shape of the silicon pieces, so the group is working to minimize them. These devices also require electrical connections of gold and titanium, which are biocompatible but not biodegradable. Rogers is developing biodegradable electrical contacts so that all that would remain is the silicon.

The group is currently designing electrodes built on silk as interfaces for the nervous system. Electrodes built on silk could, Litt says, integrate much better with biological tissues than existing electrodes, which either pierce the tissue or sit on top of it. The electrodes might be wrapped around individual peripheral nerves to help control prostheses. Arrays of silk electrodes for applications such as deep-brain stimulation, which is used to control Parkinson's symptoms, could conform to the brain's crevices to reach otherwise inaccessible regions. "It would be nice to see the sophistication of devices start to catch up with the sophistication of our basic science, and this technology could really close that gap," says Litt.

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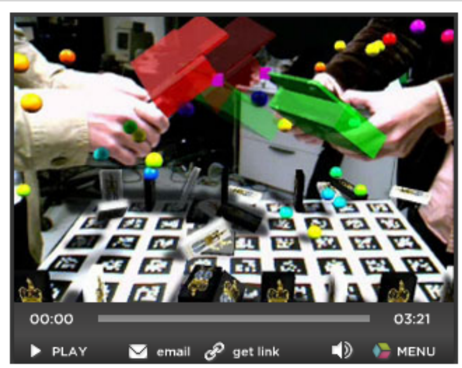

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