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Dissolvable batteries made of silk

The biodegradable batteries produce enough voltage and should last long enough to power temporary medical implants

By Prachi Patel

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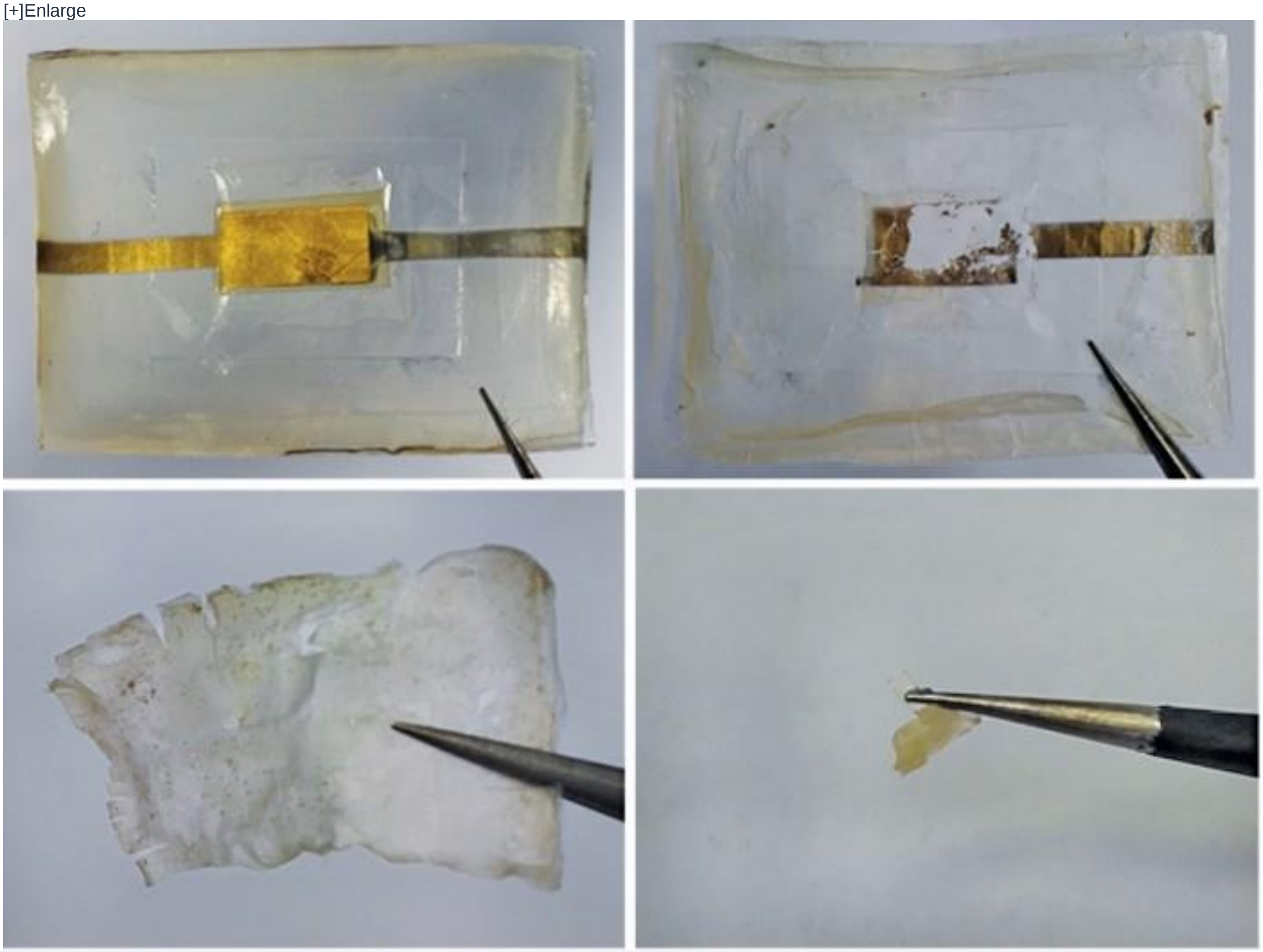

A thin battery (top left) made of metal-coated silk electrodes and a silk-ionic liquid electrolyte completely dissolves in saline buffer solution after 45 days (bottom right).

Credit: *ACS Energy Lett.*

A flexible battery made of gauzy silk films could power electronics and then melt away after a preset number of days (*ACS Energy Lett.* 2017, DOI: 10.1021/acsenergylett.7b00012). The biodegradable battery produces a high enough voltage to power temporary medical implants designed to harmlessly dissolve in the body in a few weeks once their work is done.

Scientists have been making rapid progress on medical sensors and devices that could transmit images, stimulate wounds to heal, or deliver drugs for a short while before degrading. Most prototypes of these devices have been powered from an external source so they can only be placed skin-deep. To work deeper in the body, the devices will need an on-board power source.

Dissolvable batteries are an ideal solution. Researchers have made such batteries before using natural, biocompatible materials for the electrodes and electrolytes. One team made electrodes out of the skin pigment melanin, while others have used thin foils of magnesium or iron. The electrolytes have typically been solutions of various salts in water, but liquid electrolytes can leak out and degrade battery electrodes, and they make batteries relatively bulky.

In a fresh spin on degradable batteries, Caiyun Wang and Gordon G. Wallace of the University of Wollongong and colleagues made electrodes and a solid electrolyte out of silk. The solid electrolyte enables thinner, flatter, and more flexible and robust batteries, says Wang. Silk is ideal for medical electronics because it can be made into thin films, is biocompatible, and is sturdy enough to work in electronic circuitry.

The researchers made the thin films that comprise the new battery by first dissolving a fibrous silk protein called fibroin, derived from silkworm cocoons, in water. They spread the solution in a mold and peeled off ultrathin films of silk after the water evaporated.

To make the electrolyte, they infused a piece of the silk membrane with the ionic liquid choline nitrate, a molten salt that is excellent at conducting ions, by adding it to the silk fibroin solution. To make electrodes, they deposited a biocompatible magnesium alloy on a piece of the silk film to form an anode and deposited gold on another piece to form a cathode.

They assembled the battery by sandwiching the electrolyte between the two electrode films and fusing together the uncoated edges with a sticky, amorphous silk film.

The postage-stamp-sized, 170-µm-thick device generated a voltage of 0.87 V and had a power density of 8.7 $\mu W/cm^2$, which would be enough to power an implantable medical sensor. Placed in a saline buffer solution, the battery showed a stable voltage for about an hour, after which the anode started breaking down. When the researchers added an extra silk film on top of the anode, the voltage remained stable for nearly two hours. Previously reported biodegradable batteries have lasted for about 15 minutes.

The device nearly completely decomposed after 45 days in the solution, leaving behind inert gold nanoparticles, which would be cleared by the body. By adjusting the properties of the silk layers encapsulating the battery, Wallace says they could tailor how long it predictably generates power and how quickly it dissolves.

The silk-ionic liquid electrolyte improves the performance of magnesium-based decomposable batteries, says Christopher J. Bettinger of Carnegie Mellon University. “These batteries can maintain a pretty high voltage for a relatively long amount of time,” he says. For medical applications it would be important to consider the toxicity of the ionic liquids, he says, but this “could also be a compostable battery for other uses.”

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