Electrical circuit made of gel can repair itself

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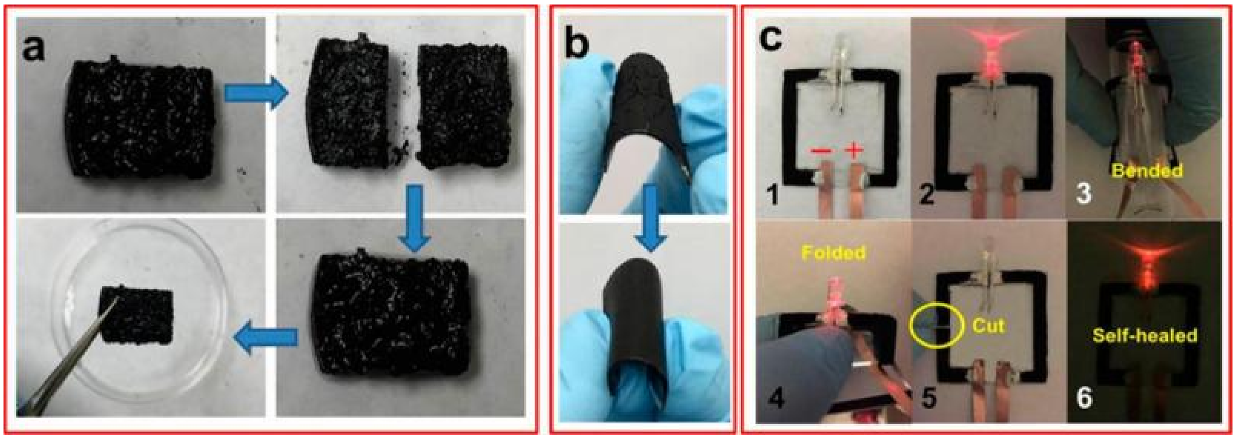

(a) After being cut in half, the conductive supergel self-heals and can support its own weight when lifted with tweezers. (b) The supergel self-heals cracks caused by bending. (c) A self-healing electric circuit that lights an LED can repair itself after being bent, cut, and folded. Credit: Shi, et al. ©2015 American Chemical Society

(Phys.org)—Scientists have fabricated a flexible electrical circuit that, when cut into two pieces, can repair itself and fully restore its original conductivity. The circuit is made of a new gel that possesses a combination of properties that are not typically seen together: high conductivity, flexibility, and room-temperature self-healing. The gel could potentially offer self-healing for a variety of applications, including flexible electronics, soft robotics, artificial skins, biomimetic prostheses, and energy storage devices.

The researchers, led by Guihua Yu, an assistant professor at the University of Texas at Austin, have published a paper on the new self-healing gel in a recent issue of *Nano Letters*.

The new gel's properties arise from its hybrid composition of two gels: a supramolecular gel, or 'supergel', is injected into a conductive polymer hydrogel matrix. As the researchers explain, this "guest-to-host" strategy allows the chemical and physical features of each component to be combined.

The supergel, or the "guest," provides the self-healing ability due to its supramolecular chemistry. As a supramolecular assembly, it consists of large molecular subunits rather than individual molecules. Due to its large size and structure, the assembly is held together by much weaker interactions than normal molecules, and these interactions can also be reversible. This reversibility is what gives the supergel its ability to act like a "dynamic glue" and reassemble itself.

Meanwhile, the conductive polymer hydrogel, or the "host," contributes to the conductivity due to its nanostructured 3D network that promotes electron transport. As the backbone of the hybrid gel, the hydrogel component also reinforces its strength and elasticity. When the supergel is injected into the hydrogel matrix, it wraps around the hydrogel in such a way as to form a second network, further strengthening the hybrid gel as a whole.

In their experiments, the researchers fabricated thin films of the hybrid gel on flexible plastic substrates to test their electrical properties. The tests showed that the conductivity is among the highest values of conductive hybrid gels, and is maintained due to the self-healing property even after repeated bending and stretching. The researchers also demonstrated that, when an electrical circuit made of the hybrid gel is cut, it takes about one minute for the circuit to self-heal and recover its original conductivity. The gel self-heals even after being cut multiple times in the same location.

The researchers explained that the conductive self-healing material has a variety of potential applications.

"The conductive self-healing gel we developed can be applied in many technologic areas, from flexible/stretchable electronics, artificial skins, energy storage and conversion devices, to biomedical devices," Yu told *Phys.org*. "For example, the gel can be potentially used in implantable biosensors as flexible yet self-healable electrodes, ensuring the durability of these devices. And in energy devices, for example, the gel can function as binder materials for advanced battery electrodes in high-density Li-ion batteries where high-capacity electrodes may experience substantial volume changes."

The researchers also hope that, by combining supramolecular chemistry and polymer nanoscience, the resulting hybrid gels may provide a useful strategy for designing new self-healing materials.

"We are planning to investigate the fundamental mechanisms of the self-healing properties of supramolecular gels and to better understand how different key factors, such as different metal ions, the molecules' geometries, and the interactions between the supramolecule and different solvents, affect the self-healing characteristics," Yu said. "A deeper fundamental understanding will allow better materials to be developed. Meanwhile, from a more 'practical applications' standpoint, some research efforts (together with our collaborators) will be devoted to developing scalable synthetic strategies of supramolecules and self-healing hybrid gels with even better mechanical strength and elasticity, for potential applications of these self-healing gels in different technology areas."

More information: Ye Shi, et al. "A Conductive Self-Healing Hybrid Gel Enabled by Metal-Ligand Supramolecule and Nanostructured Conductive Polymer." *Nano Letters*. DOI: 10.1021/acs.nanolett.5b03069