Self-adaptive material heals itself, stays tough

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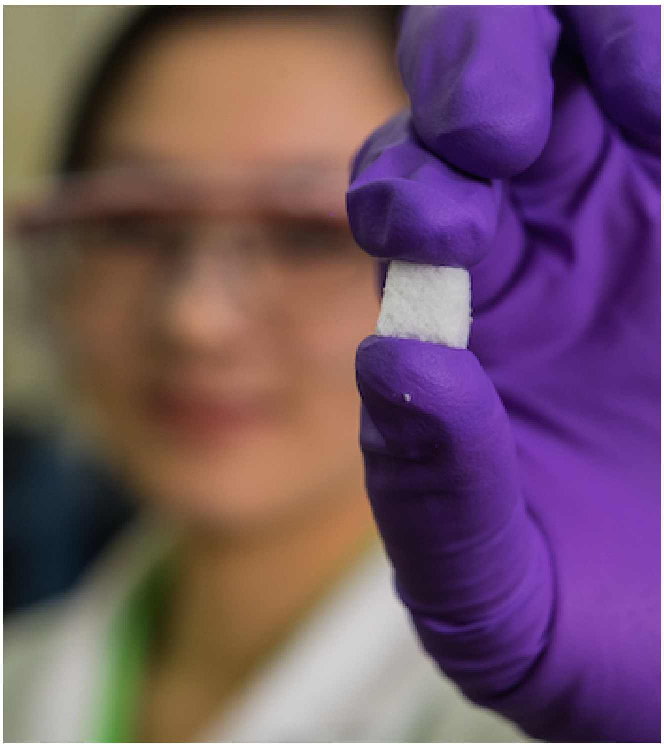


Rice University postdoctoral researcher Pei Dong holds a sample of SAC, a new form of self-adapting composite. The material has the ability to heal itself and to regain its original shape after extraordinary compression. Credit: Jeff Fitlow/Rice University

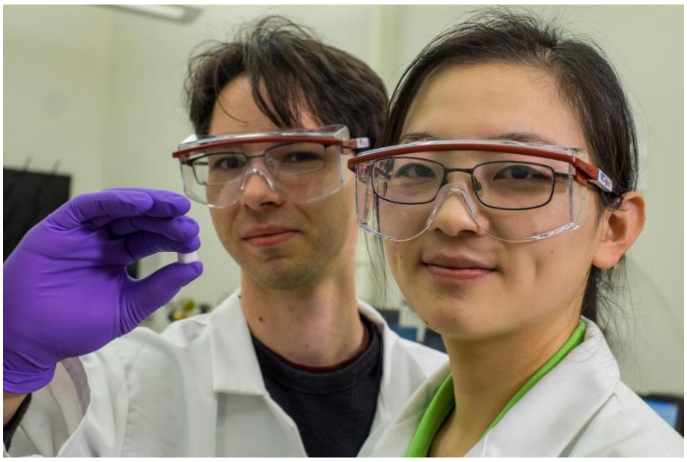
An adaptive material invented at Rice University combines self-healing and reversible self-stiffening properties.

The Rice material called SAC (for self-adaptive composite) consists of what amounts to sticky, micron-scale rubber balls that form a solid matrix. The researchers made SAC by mixing two polymers and a solvent that evaporates when heated, leaving a porous mass of gooey spheres. When cracked, the matrix quickly heals, over and over. And like a sponge, it returns to its original form after compression.

The labs of Rice materials scientists Pulickel Ajayan and Jun Lou led the study that appears in the American Chemical Society journal *ACS Applied Materials and Interfaces*. They suggested SAC may be a useful biocompatible material for tissue engineering or a lightweight, defect-tolerant structural component.

Other "self-healing" materials encapsulate liquid in solid shells that leak their healing contents when cracked. "Those are very cool, but we wanted to introduce more flexibility," said Pei Dong, a postdoctoral researcher who co-led the study with Rice graduate student Alin Cristian Chipara. "We wanted a biomimetic material that could change itself, or its inner structure, to adapt to external stimulation and thought introducing more liquid would be a way. But we wanted the liquid to be stable instead of flowing everywhere."

In SAC, tiny spheres of polyvinylidene fluoride (PVDF) encapsulate much of the liquid. The viscous polydimethylsiloxane (PDMS) further coats the entire surface. The spheres are extremely resilient, Lou said, as their thin shells deform easily. Their liquid contents enhance their viscoelasticity, a measure of their ability to absorb the strain and return to their original state, while the coatings keep the spheres together. The spheres also have the freedom to slide past each other when compressed, but remain attached.



Rice University graduate student Alin Cristian Chipara and postdoctoral researcher Pei Dong show a sample of their self-adaptive composite, which they say shows potential for tissue engineering or lightweight structural applications. Credit: Jeff Fitlow/Rice University

"The sample doesn't give you the impression that it contains any liquid," Lou said. "That's very different from a gel. This is not really squishy; it's more like a sugar cube that you can compress quite a lot. The nice thing is that it recovers."

Ajayan said making SAC is simple, and the process can be tuned—a little more liquid or a little more solid—to regulate the product's mechanical behavior.

"Gels have lots of liquid encapsulated in solids, but they're too much on the very soft side," he said. "We wanted something that was mechanically robust as well. What we ended up with is probably an extreme gel in which the liquid phase is only 50 percent or so."

The polymer components begin as powder and viscous liquid, said Dong. With the addition of a solvent and controlled heating, the PDMS stabilizes into solid spheres that provide the reconfigurable internal structure. In tests, Rice scientists found a maximum of 683 percent increase in the material's storage modulus - a size-independent parameter used to characterize self-stiffening behavior. This is much larger than that reported for solid composites and other materials, they said.

Dong said sample sizes of the putty-like material are limited only by the container they're made in. "Right now, we're making it in a 150-milliliter beaker, but it can be scaled up. We have a design for that."

More information: Pei Dong et al. A Solid-liquid Self-adaptive Polymeric Composite, *ACS Applied Materials & Interfaces* (2015). DOI: 10.1021/acsami.5b10667

Provided by Rice University