New polymer can shape-shift into multiple forms (w/ video)

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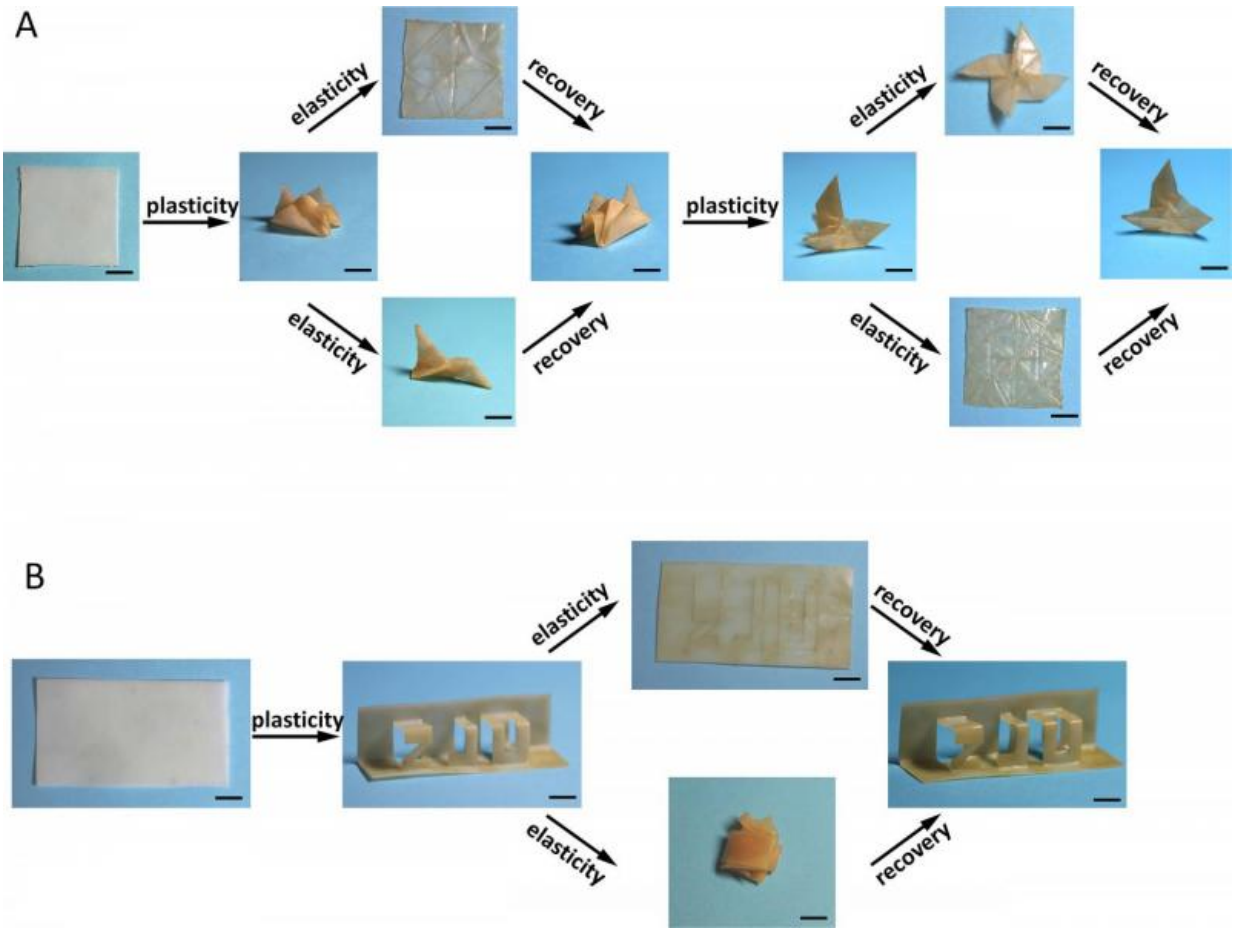

Shape manipulation via thermally distinct elasticity and plasticity. (A) Smart origami structures. (B) Smart kirigami structure. Credit: Dr. Qian Zhao and Dr. Tao Xie

(Phys.org)—A team of researchers with Zhejiang University in China has developed a new type of polymer that can be caused to revert to multiple different forms on demand. In their paper published in the journal *Science Advances*, the team describes how they came up with the new polymer, how it works and the uses to which it might be put.

In the recent past, material scientists have come up with polymers that change from one shape to another when heated or cooled—the main drawback for them has been that they can only be programmed to take one or two shapes. In this new effort, the researchers have come up with a polymer that is capable of forming itself into many different shapes, by combing two ingredients—one that has elastic deformation properties and the other that has plastic deformation properties. Current polymers tend to have the former property, which is useful for some limited applications. But what has really been needed, the team notes, is a polymer capable of plastic deformation, where it is re-shaped permanently without having to resort to melting—due to covalent bond exchange.

To make the polymer, the researchers added the chemical 1,5,7-triazabicyclo[4.4.0]dec-5-ene to an elastic material known as crosslinked poly (caprolactone) , the result was a plastic that had a low transitive temperature (55˚C) and a high deformation temperature (130˚C). The new material can be programmed by physically pushing the material into different shapes at different temperatures. To make them come about on demand, the material is subjected to the temperature that corresponds with the shape that is desired. The group created several such polymers and demonstrated that it was possible to cause the same piece of material to fold itself into first one shape, then another—in one such example a material was first caused to revert to an origami boat and then to revert to an origami flower.

The team reports that in addition to a high degree of programmability

the polymer also demonstrated toughness—it could be caused to change in to multiple different shapes over and over again without cracking or degrading. They believe the new material could likely be used in medical applications, in shape-shifting electronics, or perhaps aboard spacecraft.

More information: Q. Zhao et al. Shape memory polymer network with thermally distinct elasticity and plasticity, *Science Advances* (2016). DOI: 10.1126/sciadv.1501297

Abstract
Stimuli-responsive materials with sophisticated yet controllable shape-changing behaviors are highly desirable for real-world device applications. Among various shape-changing materials, the elastic nature of shape memory polymers allows fixation of temporary shapes that can recover on demand, whereas polymers with exchangeable bonds can undergo permanent shape change via plasticity. We integrate the elasticity and plasticity into a single polymer network. Rational molecular design allows these two opposite behaviors to be realized at different temperature ranges without any overlap. By exploring the cumulative nature of the plasticity, we demonstrate easy manipulation of highly complex shapes that is otherwise extremely challenging. The dynamic shape-changing behavior paves a new way for fabricating geometrically complex multifunctional devices.