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MOLECULE TURNS RED AT BREAKING POINT

Materials hosting the right chemical may offer a colorful signal of stress

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FEELING THE STRETCH
A polymer spiked with a color-changing molecule turns red seconds before it snaps. The technology may one day allow damage to be easily spotted.
D. Stevenson, A. Jerez, A. Hamilton and D. Davis

Engineers one day may not have to guess when a bridge is about to break. New materials that flush red in response to damage may provide a visible warning sign of trouble to come, scientists report in the May 7 *Nature*.

“I think it could be a milestone,” says Christoph Weder, a polymer chemist at Case Western Reserve University in Cleveland and at the University of Fribourg in Switzerland, who wrote a commentary in the same issue of *Nature*.

The materials’ chameleon-like abilities are thanks to a small four-ringed molecule called a mechanophore. When the weakest bond in the mechanophore breaks, the molecule creates a dog-bone shape, and the reaction causes the molecule to redden.

“It’s a really simple detection method,” says study coauthor Nancy Sottos, a materials scientist at the Beckman Institute for Advanced Science and Technology at the University of Illinois at Urbana-Champaign. “We’re opening up this one bond, and it changes color.”

But the small color-changing molecule isn’t so useful on its own, she says. "It’s hard to apply force to something so small, so we hooked it into the backbone of a long polymer. That’s the trick.”

Sottos and her colleagues spiked two kinds of polymers — a stretchy, soft one and a hard, glassy one — with the molecule. The team tested the first material, which stretched about as much as a Stretch Armstrong doll, by pulling on it until it

broke. The bright red color appeared a few seconds before the material snapped, suggesting the molecules acted as an early warning sign that the material had incurred damage. In another test, the researchers mimicked repetitive stress by repeatedly stretching and relaxing the soft polymer. “After a few cycles of that, we got this brilliant color change in the material, without it breaking,” Sottos says.

Hard, glasslike beads of a second polymer also changed color when the beads were squeezed, indicating that the color change was indeed due to mechanical forces.

Other researchers have done neat tricks with color-changing molecules but never before in a solid, Weder says. “The question is can you do this in a nice solid material? And this is what they have done.”

Sottos says the material could eventually be used to make solid objects including rollerblade wheels, thin films such as coats of paint, or even thin fibers that could turn red when tiny deformations develop.

The team is also working on another property of mechanophores: self-healing. Shining bright light on the molecule triggers the broken bond to re-form, at which point the red warning disappears.

But this ability to heal introduces a new problem. If light can trigger the molecule to lose its red color, then color won’t be a reliable indicator of damage to the material as a whole, Weder says.

“This is really a proof-of-concept paper,” he says. “Before the material can be used as a mechanical force sensor, there are practical issues that need to be addressed,” including how light may interfere with the desired signal and how the color-change might be made permanent.