Metal-ion breakthrough leads to new biomaterials

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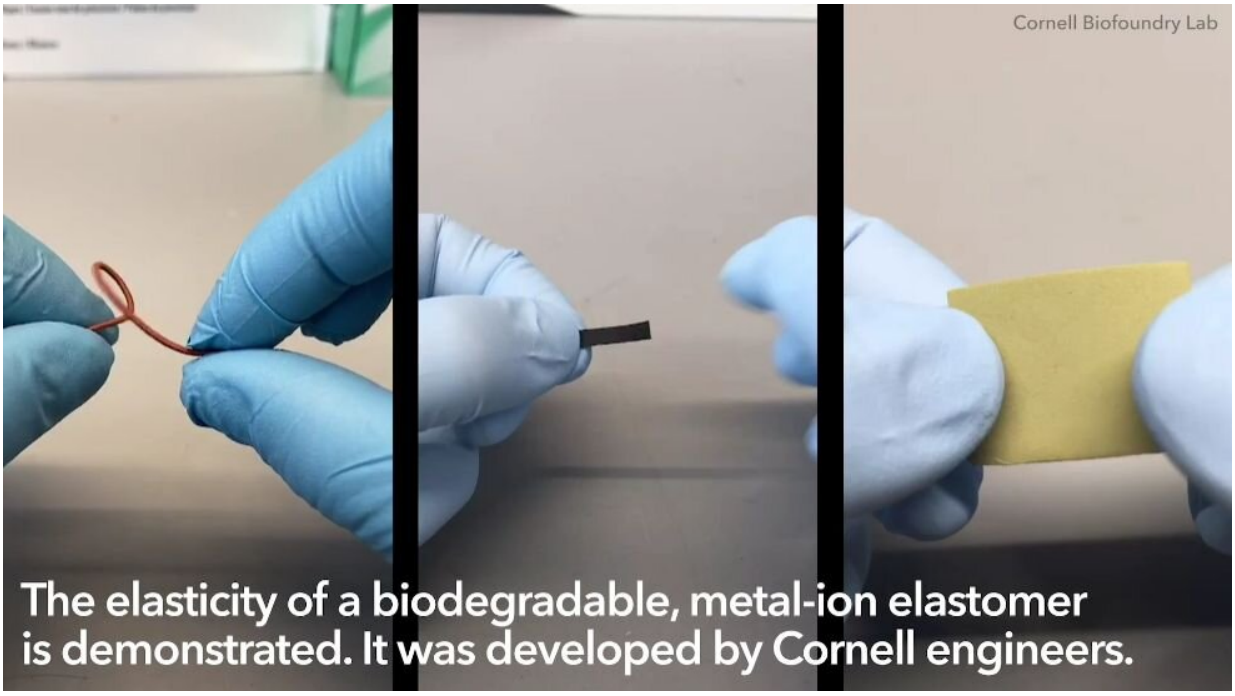

Metals such as iron and calcium play a crucial role inside the human body, so it's no surprise that bioengineers would like to integrate them into the soft, stretchy materials used to repair skin, blood vessels, lungs and other tissue.

Designing elastomers—a type of polymer with rubber-like

properties—is a laborious process that yields a product with limited versatility. But Cornell engineers have developed a new framework that makes elastomer design a modular process, allowing for the mixing and matching of different metals with a single polymer.

The framework is detailed in "Chelation Crosslinking of Biodegradable Elastomers," published Sept. 22 in *Advanced Materials*.

The framework was conceived when researchers from Cornell's Biofoundry Lab sought to create an elastic vascular graft that could help repair heart tissue using copper. Yadong Wang, the McAdam Family Foundation Professor of Cardiac Assist Technology in the Meinig School of Biomedical Engineering, and postdoctoral associate Ying Chen wanted to incorporate copper into their graft because of its role in inducing angiogenesis—the process by which new blood vessels grow from existing ones.

Mixing copper and other metal ions with polymers has remained a niche area of chemistry, so there was no blueprint for Chen to follow. Instead, she set out to engineer a biocompatible and biodegradable elastomer from scratch.

Chen's key breakthrough was crosslinking her polymer with copper ions using chelating ligands—molecules that tightly bind a metal ion using two or more bonds, "like how a crab claw pinches an object," said Wang. While chelation bonds are considered to be of moderate strength in chemistry, elastomers have many crosslinking molecules, so a multitude of chelating ligands can work together to form a strong molecule.

And because one ligand can bind multiple metal ions, it can yield a wide range of mechanical properties—such as stiffness and toughness—as well as biomedical properties. For example, a polymer's copper ions could be replaced with zinc, or a combination of copper and zinc could

be used—a tandem that is present in an important enzyme for fighting human aging.

"The discovery was pretty exciting," Chen said. "I just wanted to move on with my copper elastomer because I'm focused on tissue engineering, but Professor Wang was saying, 'Slow down, we need to test how powerful this platform is and what we can do with it.'"

As proof of concept, Chen engineered six unique elastomers using one polymer and six different metals, and then made a seventh elastomer using a calcium-magnesium mix. It was the first time anyone had demonstrated a biodegradable metal-ion elastomer—let alone seven of them.

"When Ying showed me what she had done, I said, 'This material is amazing,'" Wang said. "There's so much you can do with just this one simple design. Using many different types of metal ions, one polymer can turn into eight, nine, 10 different elastomers."

The research team also performed mechanical and biocompatibility experiments on their elastomers, testing for the materials' stress, strain and ability to be used with living tissue. The durability and biocompatibility of the elastomers matched that of more traditional biomaterials used in medicine.

"The copper material was very elastic," Chen said. "It can be stretched at least hundreds of times without rupturing."

Now that the platform has published, Chen is focusing her research on the copper elastomer graft and its ability to repair blood vessels and heart tissue. In the meantime, she hopes other engineers will use her platform to create new materials for improving soft tissue reconstruction and regeneration.

Wang shares the same hope, and said possible applications for the framework are not limited to blood vessels and other tissues, but could potentially be used for industrial elastomers such as eco-friendly tires that biodegrade.

"We are just scratching the surface," he said.

More information: Ying Chen et al, Chelation Crosslinking of Biodegradable Elastomers, *Advanced Materials* (2020). DOI: 10.1002/adma.202003761

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