4-D-printed materials can be stiff as wood or soft as sponge

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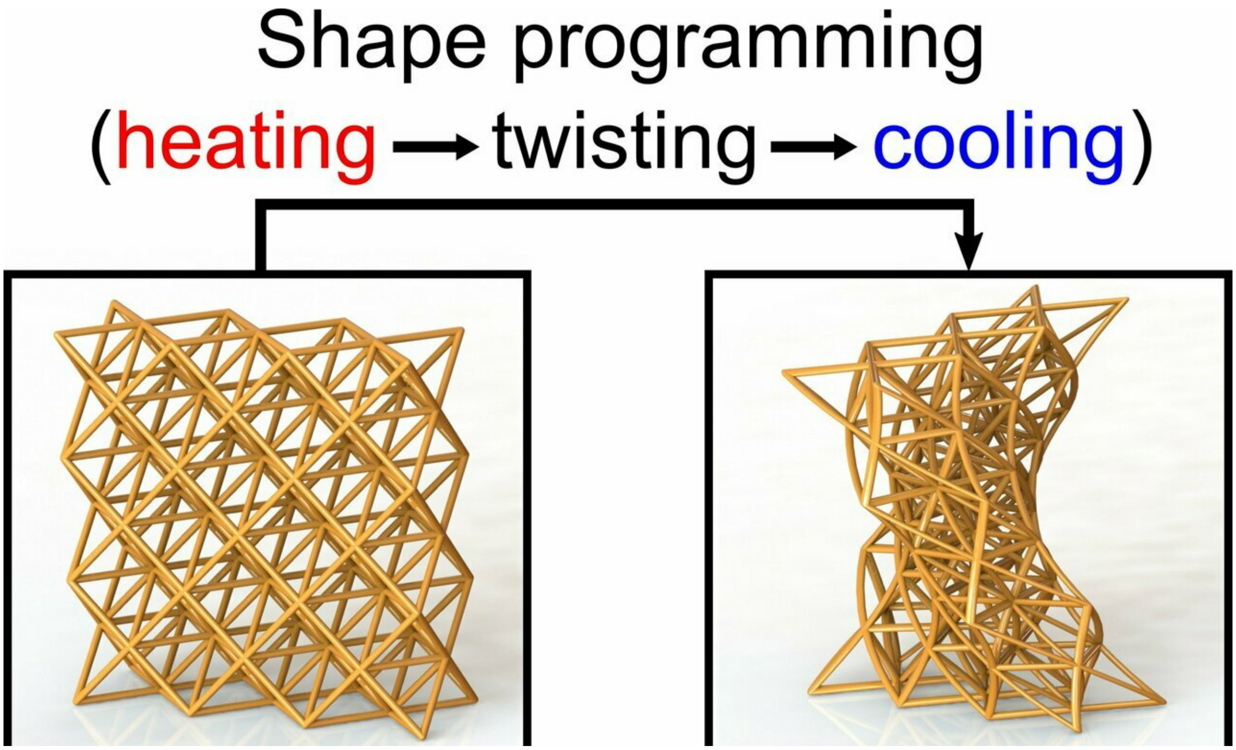

4D-printed metamaterials can be temporarily transformed into any deformed shape and then returned to their original shape on demand when heated. The scale bar is 2 millimeters. Credit: Chen Yang/Rutgers University-New Brunswick

Imagine smart materials that can morph from being stiff as wood to as soft as a sponge—and also change shape.

Rutgers University-New Brunswick engineers have created flexible, lightweight materials with 4-D printing that could lead to better shock absorption, morphing airplane or drone wings, soft robotics and tiny implantable biomedical devices. Their research is published in the journal *Materials Horizons*.

3-D printing, also known as additive manufacturing, turns digital blueprints to physical objects by building them layer by layer. 4-D printing is based on this technology, with one big difference: it uses special materials and sophisticated designs to print objects that change shape with environmental conditions such as temperature acting as a trigger, said senior author Howon Lee, an assistant professor in the Department of Mechanical and Aerospace Engineering. Time is the fourth dimension that allows them to morph into a new shape.

"We believe this unprecedented interplay of materials science, mechanics and 3-D printing will create a new pathway to a wide range of exciting applications that will improve technology, health, safety and quality of life," Lee said.

The engineers created a new class of "metamaterials—materials engineered to have unusual and counterintuitive properties that are not found in nature. The word metamaterials is derived from the Greek word "meta," which means "higher" or "beyond."

Previously, the shape and properties of metamaterials were irreversible once they were manufactured. But the Rutgers engineers can tune their plastic-like materials with heat, so they stay rigid when struck or become soft as a sponge to absorb shock.

The stiffness can be adjusted more than 100-fold in temperatures between room temperature (73 degrees) and 194 degrees Fahrenheit, allowing great control of shock absorption. The materials can be reshaped for a wide variety of purposes. They can be temporarily transformed into any deformed shape and then returned to their original shape on demand when heated.

The materials could be used in airplane or drone wings that change shape to improve performance, and in lightweight structures that are collapsed for space launches and reformed in space for a larger structure, such as a solar panel.

Soft robots made of soft, flexible and rubbery materials inspired by the octopus could have variable flexibility or stiffness that is tailored to the environment and task at hand. Tiny devices inserted or implanted in people for diagnosis or treatment could be temporarily made soft and flexible for minimally invasive and less painful insertion into the body, Lee said.

More information: Chen Yang et al, 4D Printing Reconfigurable, Deployable and Mechanically Tunable Metamaterials, *Materials Horizons* (2019). DOI: 10.1039/C9MH00302A

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