Engineers develop programming technology to transform 2-D materials into 3-D shapes

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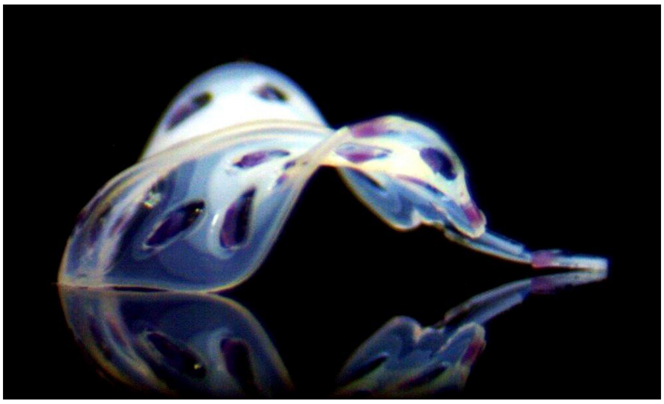

3D shape created in Yum's lab Credit: UT Arlington

University of Texas at Arlington researchers have developed a technique that programs 2-D materials to transform into complex 3-D shapes.

The goal of the work is to create synthetic materials that can mimic how living organisms expand and contract soft tissues and thus achieve complex 3-D movements and functions. Programming thin sheets, or 2-D materials, to morph into 3-D shapes can enable new technologies for soft robotics, deployable systems, and biomimetic manufacturing, which produces synthetic products that mimic biological processes.

Kyungsuk Yum, an associate professor in the Materials Science and Engineering Department, and his team have developed the 2-D material programming technique for 3-D shaping. It allows the team to print 2-D materials encoded with spatially controlled in-plane growth or contraction that can transform to programmed 3-D structures.

Their research, supported by a National Science Foundation Early Career Development Award that Yum received in 2019, was published in January in *Nature Communications*.

"There are a variety of 3-D-shaped 2-D materials in biological systems, and they play diverse functions," Yum said. "Biological organisms often achieve complex 3-D morphologies and motions of soft slender tissues by spatially controlling their expansion and contraction. Such biological processes have inspired us to develop a method that programs 2-D materials with spatially controlled in-plane growth to produce 3-D shapes and motions."

With this inspiration, the researchers developed an approach that can uniquely create 3-D structures with doubly curved morphologies and motions, commonly seen in living organisms but difficult to replicate with man-made materials.

They were able to form 3-D structures shaped like automobiles, stingrays, and human faces. To physically realize the concept of 2-D material programming, they used a digital light 4-D printing method developed by Yum and shared in Nature Communications in 2018.

"Our 2-D-printing process can simultaneously print multiple 2-D materials encoded with individually customized designs and transform them on demand and in parallel to programmed 3-D structures," said Amirali Nojoomi, Yum's former graduate student and first author of the paper. "From a technological point of view, our approach is scalable, customizable, and deployable, and it can potentially complement existing 3-D-printing methods."

The researchers also introduced the concept of cone flattening, where they program 2-D materials using a cone surface to increase the accessible space of 3-D shapes. To solve a shape selection problem, they devised shape-guiding modules in 2-D material programming that steer the direction of shape morphing toward targeted 3-D shapes. Their flexible 2-D-printing process can also enable multimaterial 3-D structures.

"Dr. Yum's innovative research has many potential applications that could change the way we look at soft engineering systems," said Stathis Meletis, chair of the Materials Science and Engineering Department. "His pioneering work is truly groundbreaking."

More information: Amirali Nojoomi et al. 2D material programming for 3D shaping, *Nature Communications* (2021). DOI: 10.1038/s41467-021-20934-w

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