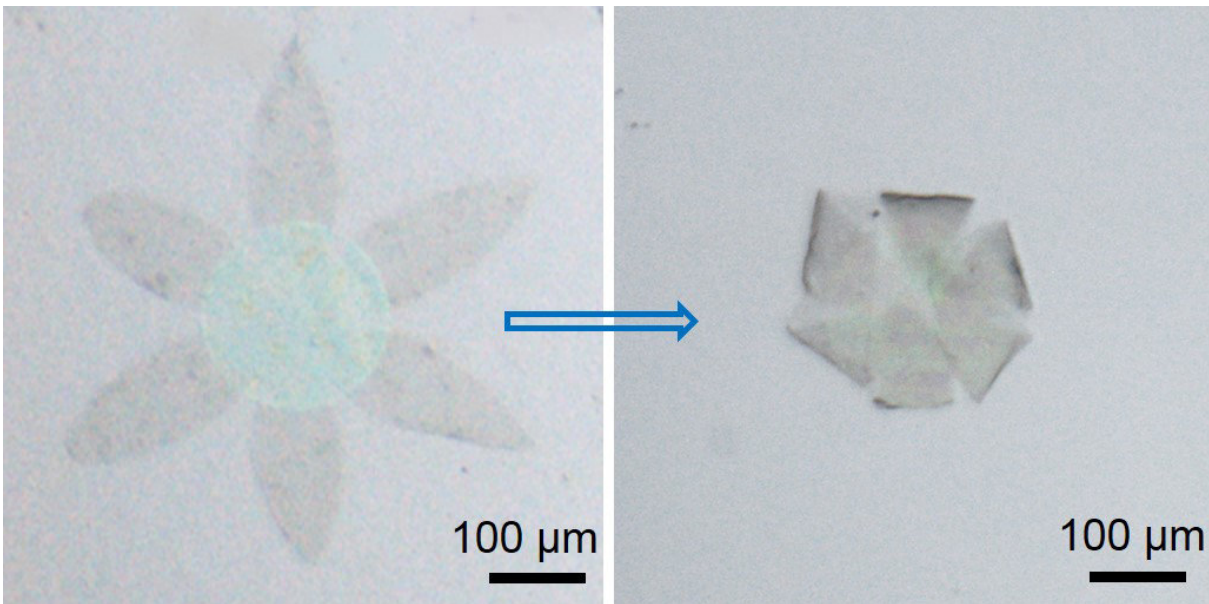


A way to cause graphene to self-fold into 3-D shapes

October 9 2017, by Bob Yirka



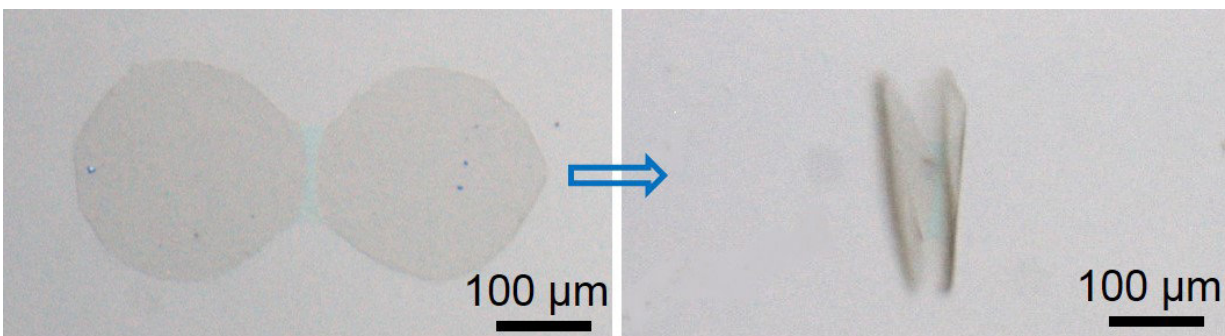
Temperature induced self-folding of a functionalized graphene flower. Credit: Weinan Xu, Johns Hopkins University

(Phys.org)—A team of researchers with Johns Hopkins University and MIT has found a way to cause flat sheets of graphene to self-fold into 3-D geometric shapes. In their paper published on the open access site *Science Advances*, the group explains how they prepared the sheets and then used heat to cause them to fold.

Graphene has been in the news a lot over the past decade, as its unique properties could lead to the development of a host of new applications. Some likely applications include biosensors and [wearable electronics](#). Before such devices can be created, however, a means must be found to create three dimensional objects from [flat sheets](#) of the material. Up until now, most methods have involved etching or applying the sheets to a substrate that conforms to a desired [shape](#). Both methods leave much to be desired; thus, researchers continue to seek a better solution. In this new effort, researchers have developed a micropatterning [technique](#) that leads to the flat [graphene](#) sheets bending along predesignated lines when heat is applied, causing the [sheet](#) to form into shapes—much like origami forms when manipulated by human hands.

One of the main benefits of the new approach is that it preserves the intrinsic properties of the graphene, which has been the goal all along—after all, what is the point of using graphene in the first place if you have to diminish its unique attributes to make it conform to a desired shape? Another benefit is that the creases can cause a band gap in the graphene, which graphene notoriously lacks in its natural state.

The team notes that the technique is also compatible with traditional lithography and can be applied at the wafer scale. Also, it is highly parallel, which means it should not present manufacturing problems. They also report that they tested their technique by creating 3-D shapes that were used to hold living cells and nonlinear resistors. They also used one in the creation of a transistor device. By creating such useful 3-D structures, the team believes they have shown that their technique could be used to build viable wearable electronic devices and sensors that could be used inside of a living organism.



Temperature induced self-folding of a functionalized graphene dumbbell. Credit: Weinan Xu, Johns Hopkins University

More information: Weinan Xu et al. Ultrathin thermoresponsive self-folding 3D graphene, *Science Advances* (2017). [DOI: 10.1126/sciadv.1701084](https://doi.org/10.1126/sciadv.1701084)

Abstract

Graphene and other two-dimensional materials have unique physical and chemical properties of broad relevance. It has been suggested that the transformation of these atomically planar materials to three-dimensional (3D) geometries by bending, wrinkling, or folding could significantly alter their properties and lead to novel structures and devices with compact form factors, but strategies to enable this shape change remain limited. We report a benign thermally responsive method to fold and unfold monolayer graphene into predesigned, ordered 3D structures. The methodology involves the surface functionalization of monolayer graphene using ultrathin noncovalently bonded mussel-inspired polydopamine and thermoresponsive poly(N-isopropylacrylamide) brushes. The functionalized graphene is micropatterned and self-folds into ordered 3D structures with reversible deformation under a full control by temperature. The structures are characterized using

spectroscopy and microscopy, and self-folding is rationalized using a multiscale molecular dynamics model. Our work demonstrates the potential to design and fabricate ordered 3D graphene structures with predictable shape and dynamics. We highlight applicability by encapsulating live cells and creating nonlinear resistor and creased transistor devices.

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Citation: A way to cause graphene to self-fold into 3-D shapes (2017, October 9) retrieved 9 April 2024 from <https://phys.org/news/2017-10-graphene-self-fold-d.html>

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