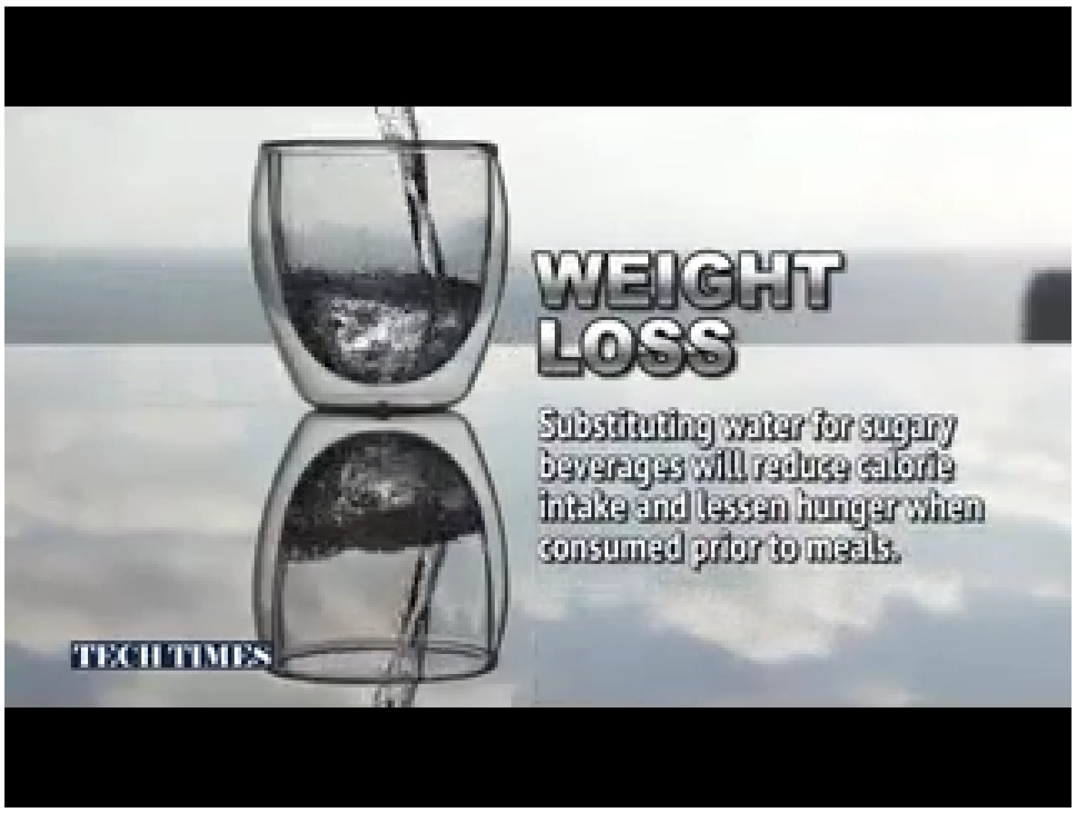
Hexagonal Boron Nitride Dubbed the Toughest 2D Materials, Here's Why

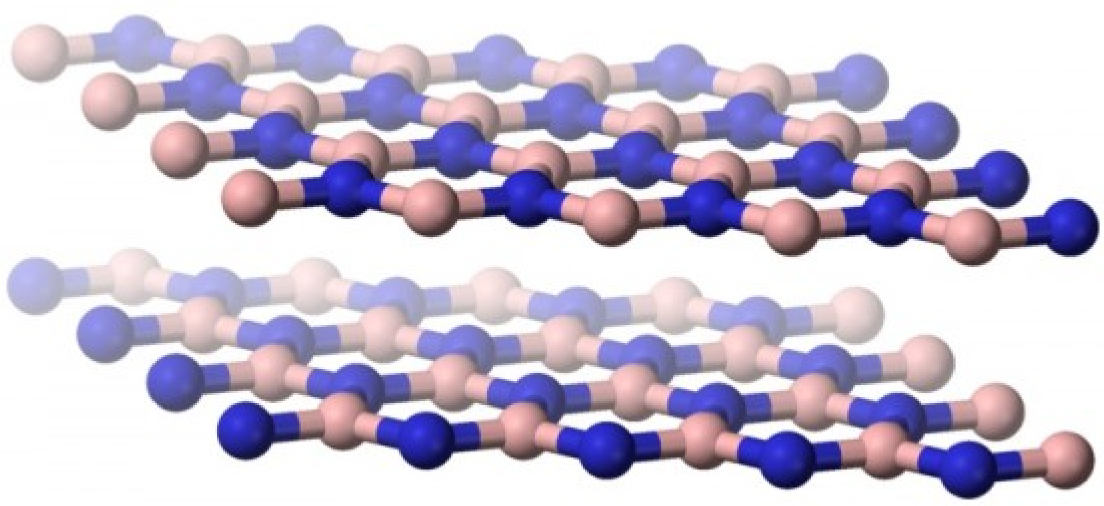
Mark Bustos Jun 03, 2021 07:09 AM EDT



Hexagonal boron nitride (h-BN) has been identified as the toughest among 2D materials - its unparalleled resistance to breakage has defied an old method of describing toughness.

In materials science, toughness is usually defined by a material's ability to absorb energy and withstand cracking and fractures. According to Jun Lou, corresponding author of a new study from the Department of Materials Science and NanoEngineering at Rice University, their observations in the 2D material is "remarkable." He adds that the fact that this behavior was not expected from this class of materials only adds to the excitement.

Researchers presented their findings in the article "Intrinsic toughening and stable crack propagation in hexagonal boron nitride," published in the journal Nature, June 2.



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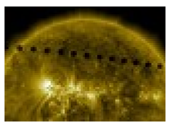

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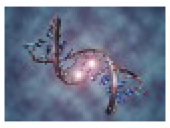

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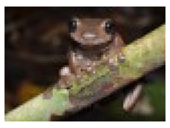

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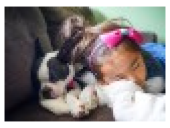

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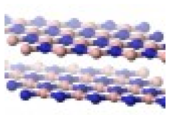
Uncovering Why Hexagonal Boron Nitride is the Toughest of the 2D Materials



The Problem with Graphene

To put the remarkable discovery in context, a more popular choice among 2D materials is graphene. Both hexagonal boron nitride and graphene are structurally similar, where atoms of the materials are arranged in a hexagonal lattice only a few atoms thick. Where graphene has an ordered structure of carbon atoms, h-BN contains a hexagon of nitrogen and borons taking three vertices each.

While the carbon to carbon bonds in graphene are among the strongest bonds in nature, the material is surprisingly delicate. Graphene is durable, which makes it a favorite among materials scientists working for a variety of applications. However, have a few carbon atoms out of place, and the performance of the material drops drastically. And according to Lou, perfect materials don't occur in the real world - they will most likely have a defect somewhere. This also stresses the importance of fracture toughness in engineering and materials science since it describes the capability of a material to withstand external forces before failing.

"We measured the fracture toughness of graphene seven years ago, and it's actually not very resistant to fracture," Lou said in a Rice University news article. He adds that if there is a crack in the graphene structure, a small load is enough to break the material.

Basically, graphene is a brittle material. In 1921, British engineer Alan Arnold Griffith published "The Phenomena of Rupture and Flow in Solids," It provided insights on how brittle materials behave and begin to fail, particularly describing the relationship between the characteristics of a crack in the material's surface and the force needed to make this fracture grow.

Hexagonal Boron Nitride: The "Iron Man" of 2D Materials

A 2014 study also including Jun Lou, titled "Fracture toughness of graphene" and appearing in Nature Communications, characterized graphene and how it follows Griffith's criterion for brittle materials. Since h-BN is structurally similar to graphene, Lou and colleagues expected similar behavior.

However, hexagonal boron nitride showed to have a toughness of about 10 times more compared to graphene. Furthermore, its behavior against fracture tests was unexpected, defying descriptions in Griffith's formula. But to show how exactly a material much like graphene had an unbelievable toughness took more than 1,000 hours of experiments at Rice University. This experimental effort was coupled with an equally laborious theoretical work led by Huajian Gao, the corresponding author in the study from Singapore's Nanyang Technological University.

This newfound strength has been credited to the slight asymmetries coming from the fact that h-BN contains two different atoms compared to graphene having only carbon in its structure. Additionally, while the theoretical mechanisms behind it are complex, Lou explains that basically, cracks in h-BN tend to "branch and turn" as compared to cracks in graphene that run straight across the material.