Researchers develop ultra-strong aerogels with materials used in bullet-proof vests

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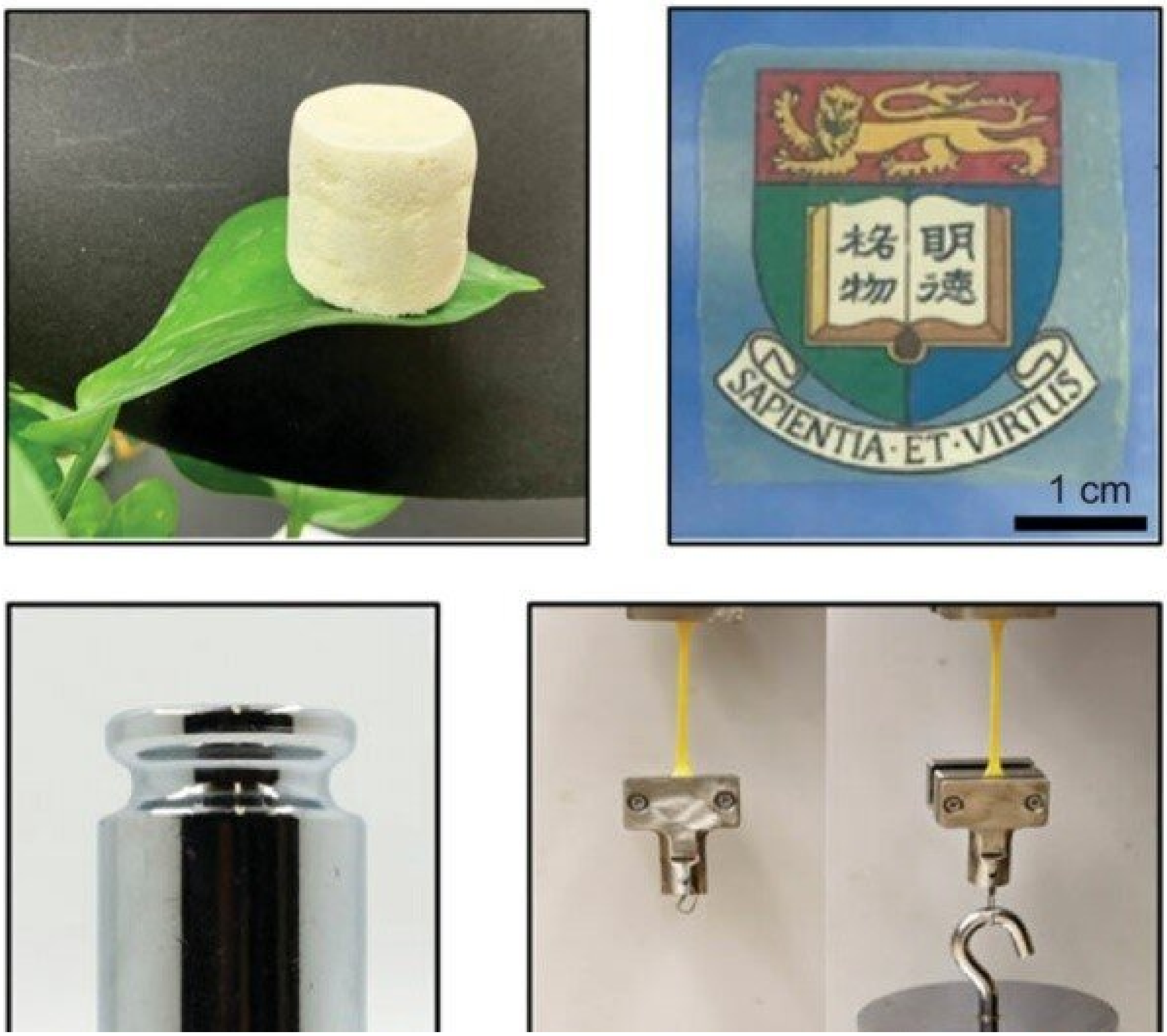


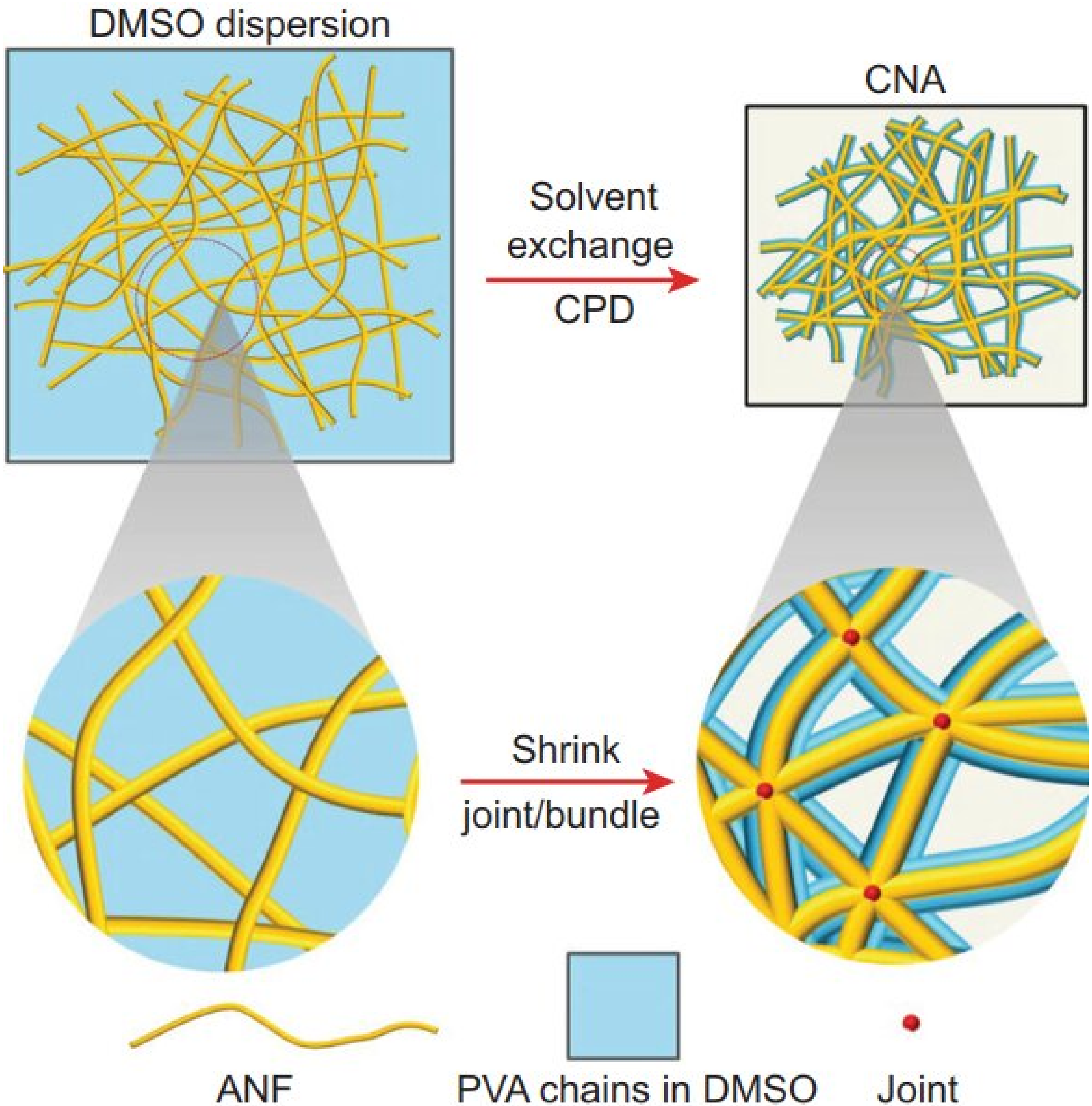
The aerogels possess desirable features such as lightweight, semi-transparent and high load bearing capability. Credit: The University of Hong Kong

Aerogels are lightweight materials with extensive microscale pores, which could be used in thermal insulation, energy devices, aerospace structures, as well as emerging technologies of flexible electronics. However, traditional aerogels based on ceramics tend to be brittle, which limits their performance in load-bearing structures. Due to restrictions posed by their building blocks, recently developed classes of polymeric aerogels can only achieve high mechanical strength by sacrificing their structural porosity or lightweight characteristics.

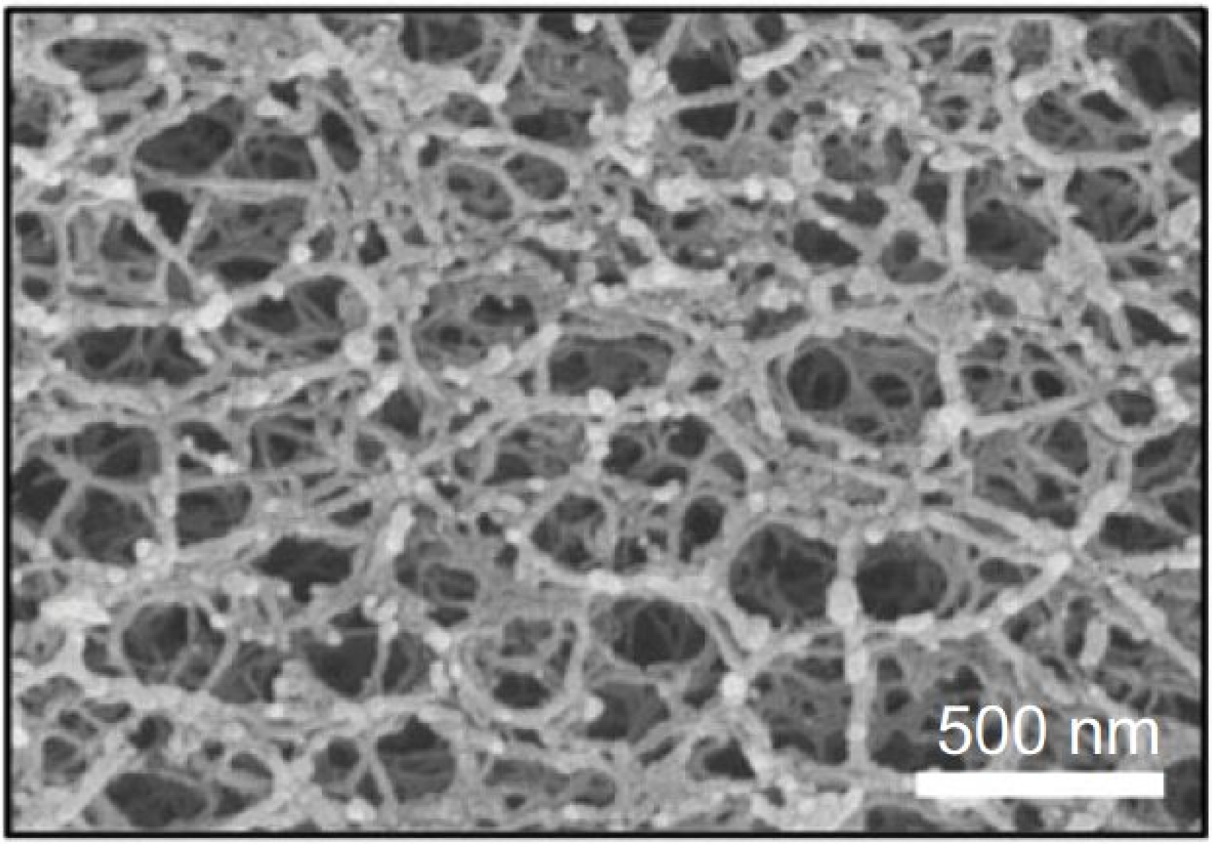
A research team led by Dr. Lizhi Xu and Dr. Yuan Lin from the Department of Mechanical Engineering of the Faculty of Engineering of the University of Hong Kong (HKU), has developed a new type of polymer aerogel materials with vast applicational values for diverse functional devices.

In this study, now published in *Nature Communications*, a new type of aerogel was successfully created using a self-assembled nanofiber network involving aramids, or Kevlar, a polymer material used in bullet-proof vests and helmets. Instead of using millimeter-scale Kevlar fibers, the research team used a solution-processing method to disperse the aramids into nanoscale fibrils.

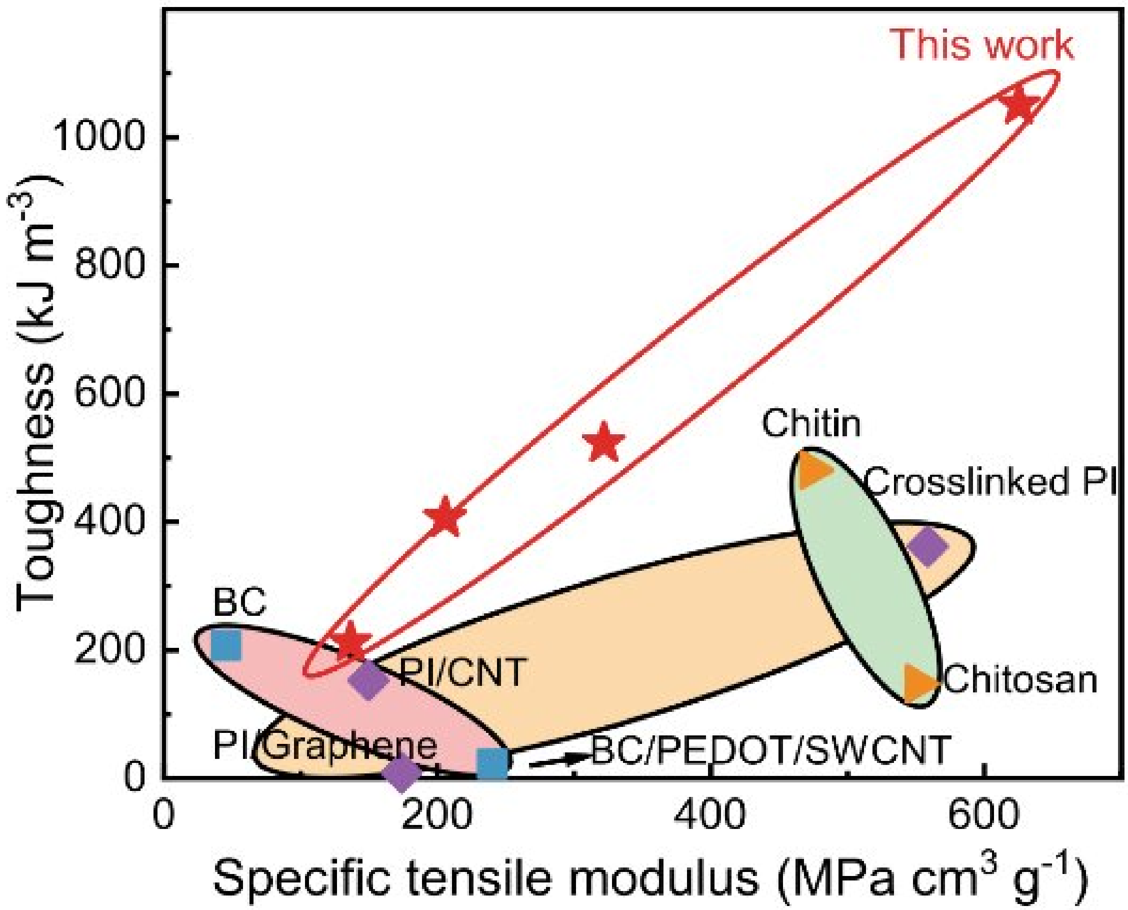
The interactions between the nanofibers and polyvinyl alcohol, another soft and "gluey" polymer, generated a 3D fibrillar network with high nodal connectivity and strong bonding between the nanofibers. "It's like a microscopic 3D truss network, and we managed to weld the trusses firmly together, resulting in a very strong and tough material that can withstand extensive mechanical loads, outperforming other aerogel materials," said Dr. Xu.



Schematics of the assembly process of the composite nanofiber aerogels. Credit: The University of Hong Kong



Scanning electron microscope image showing the micro-structure of the aerogel materials. Credit: The University of Hong Kong



Both high toughness and tensile modulus are achieved by the composite nanofiber aerogels, when compared to other polymeric aerogels. Credit: The University of Hong Kong

The team has also used theoretical simulations to explain the outstanding mechanical performance of the developed aerogels. "We constructed a variety of 3D network models in computer, which captured the essential characteristics of nanofibrillar aerogels," said Dr. Lin, who led the theoretical simulations of the research.

"The nodal mechanics of fibrillar networks are essential to their overall mechanical behaviors. Our simulations revealed that the nodal connectivity and the bonding strength between the fibers influenced the mechanical strength of the network by many orders of magnitudes even with the same solid content," said Dr. Lin.

"The results are very exciting. We not only developed a new type of polymer aerogels with excellent mechanical properties but also provided insights for the design of various nanofibrous materials," said Dr. Xu, adding, "the simple fabrication processes for these aerogels also allow them to be used in various functional devices, such as wearable electronics, thermal stealth, filtration membranes, and other systems,"

More information: Huimin He et al, Ultrastrong and multifunctional aerogels with hyperconnective network of composite polymeric nanofibers, *Nature Communications* (2022). DOI: 10.1038/s41467-022-31957-2

Provided by The University of Hong Kong

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