

Fig. 1. Schematic shows the fabrication of LDH nanosheets and their use as a barrier layer on a transparent substrate.

“As an oxygen barrier, [our material] performs around 40 times better than metallized films and also fares well in the industry’s ‘crumple test’, which involves flexing and twisting it,” says O’Hare.

The researchers believe that their nanosheet film could be much more economical in terms of both cost and the environment. There will be a long development and regulatory process ahead, cautions

O’Hare, but the next stage will see sponsor SGC Chemicals up-scale the technology and produce trial packaging for a range of different foods.

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## Polar bear hair inspires carbon tube thermal insulator

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The exceptional properties of polar bear hair have inspired researchers from the University of Science and Technology of China, Hefei to design a thermal insulating material based on mats of tiny interconnected carbon tubes [Zhan et al., *Chem* 5 (2019) 1–12, <https://doi.org/10.1016/j.chempr.2019.04.025>].

Polar bear hair, which is made from keratin fibers, has a unique hollow core structure to help insulate the animal against extremely cold temperatures. To mimic the hair’s thermal insulating properties, the researchers created an aerogel composed of lightweight, interconnected carbon tubes.

“Inspired by the unique hollow microstructure of the polar bear hair, we have developed a simple solution-based process to fabricate a macroscopic carbon tube aerogel with tunable shell thickness,” explains Shu-Hong Yu, who led the work along with Jian-Wei Liu and Yong Ni.

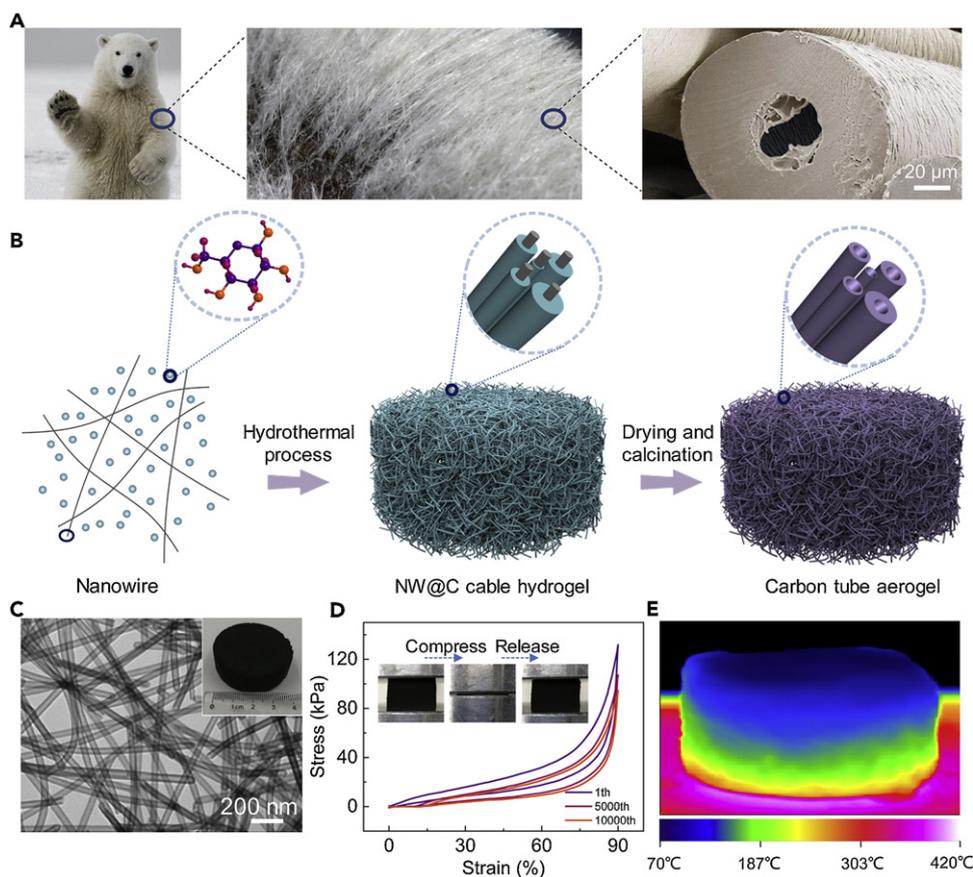
The team used tellurium nanowires as a template to fabricate the carbon tubes with diameters ranging from 25 nm to 55 nm and varying shell thickness (Fig. 1). First, the nanowires are coated with glucose, which is carbonized using a hydrothermal process to form a hydrogel. The hydrogel is then dried to create an aerogel and

calcinated in an inert atmosphere at high temperature to remove the tellurium nanowire template. Samples of the aerogel up to 4 cm in diameter were made in this way, but the process could be easily scaled up to produce larger quantities.

Despite its light weight, and exceptionally low density of 8 kg/m<sup>3</sup>, the aerogel is remarkably robust demonstrating the capability to withstand over one million compress-release cycles with 30% strain and 10,000 cycles with 90% strain. The material is also super-elastic, showing very fast rebound times when hit by a falling steel ball. The researchers credit the interconnected nature of the carbon tubes, which can deform and rotate when strained and spring back without fracturing, for the mechanical properties of the aerogel.

Most importantly of all, the carbon tube aerogel has an extremely low thermal conductivity (of 23 mW m<sup>-1</sup> K<sup>-1</sup>), which is less than dry air. In fact, according to the researchers, the carbon tube aerogel performs better than many other commercially available thermal insulating materials.

“Polar bear hair utilizes a hollow, non-wettable structure to keep [the animal] warm in cold, humid environments,” says Liu. “The



**Fig. 1.** (A) Optical and scanning electron microscope images of polar bear hair. (B) Schematic illustration of the fabrication process. (C) Transmission electron microscope image of the carbon tube aerogel. (D) Stress-strain curves of carbon tube aerogel at 90% for 10,000 cycles. (E) Thermographic image of carbon tube aerogel on a hot plate at 400 °C. Reprinted from Zhan et al., *Chem* 5 (2019) 1–12, with permission from Elsevier.

hollow structure of the hair makes it lightweight, which is one of its most outstanding advantages, [and] contributes to limiting the free flow of air, dramatically decreasing the thermal conductivity of a material. The hollow structure of our carbon tube fibers decreases the thermal conductivity because the inner diameter (35 nm) is lower than the mean free path of air (75 nm)."

The carbon tube aerogel is also water resistant, making it both waterproof and able to withstand being stored for in humid conditions without deterioration, unlike many conventional thermal insulating materials.

"The thermal insulating properties of traditional SiO<sub>2</sub>, polymer, cellulose, and phenolic resin aerogels degenerate gradually because of their higher water absorption," points out Liu. "The thermal conductivity of our material stays constant even after 120 days of storage at 56% humidity at room temperature."

The researchers believe that the excellent thermal insulation properties, mechanical stability, and chemical inertness of their biomimetic carbon tube aerogel could be ideal for high-performance, lightweight, super-elastic insulating materials for aerospace applications in extreme conditions. Urszula Stachewicz of AGH University of Science and Technology in Poland comments:

"The researchers fabricated a macroscopic-scale and lightweight carbon tube aerogel with super-elasticity and excellent thermal insulation properties, which is an amazing material."



**Cordelia Sealy** has many years' experience as a scientific journalist and editor in areas spanning nanotechnology, materials science and engineering, physics and chemistry. She has served as Editor of *Materials Today* and *Nano Today*, and more latterly as Managing Editor of both titles. She has also worked in academic publishing as a books acquisitions editor and in business-to-business publishing as a journalist on *European Semiconductor*. She has a First in Physical Sciences (BSc) from University College London and a DPhil in materials science from the University of Oxford, and is a Member of the Institute of Physics. Cordelia is currently a freelance science writer for her own company, Oxford Science Writing, and News and Opinions Editor for *Nano Today*.

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