

**Fig. 1.** Structure-enabled exquisite control of quantum states of electrons in gold nanoclusters.

2.86 Å and the carrier lifetime is longer. In the regular face-centered cubic arrangement, the distance between neighboring Au<sub>4</sub> tetrahedral units is 3.0 Å, but they take up a double-helix-like arrangement that allows relatively efficient energy transfer. Consequently, face-centered cubic NCs demonstrate an intermediate carrier lifetime of around 100 ns.

The researchers' findings indicate that structure rather than size is the crucial factor in determining carrier lifetimes in very small Au NCs.

"The strategy of manipulating the excited-state lifetime from very short to very long is exciting," points out Jin. "Our results demonstrate that the atomic packing structure, which houses electrons, can greatly affect their excited-state lifetimes, providing a

means for exquisite control. Such results open a new door to quantum manipulation, which is of tremendous importance in exploring new nanoscale phenomena and designing nanodevices."

Now the researchers plan to turn their attention to the effects of doping and alloying on carrier lifetimes and hopes to establish a set of rules for controlling the quantum behavior of electrons.

Jin Ho Bang of Hanyang University in Korea believes that the work represents a very important breakthrough, which will help to advance metal nanoclusters as an active material for optoelectronic applications.

"Metal nanoclusters with discrete electronic structures are a relatively new class of photoactive materials that provide exciting new opportunities for light energy conversion applications," he comments. "One of the important aspects of these applications is the excited state lifetime of a photoactive material. Usually, however, the excited state lifetime of metal nanoclusters tends to decrease with the decrease in the HL gap. Zhou et al. have now shown that may not always be the case."

As well as demonstrating that body-centered cubic NCs have three orders of magnitude longer excited state lifetimes than hexagonal close-packed NCs with a similar HL gap, the researchers have also identified the origin of the dramatic difference, he points out.

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## Inorganic nanosheets make food packaging recyclable

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Researchers from the University of Oxford have developed a nanotoxic food packaging film that effectively keeps out air and moisture but is easier to recycle than currently used materials [Yu et al., *Nature Communications* (2019) 10:2398, <https://doi.org/10.1038/s41467-019-10362-2>]. Packaging materials for food such as crisps and coffee are made from several layers bonded together, usually polyethylene terephthalate or PET and thin metallized layers of aluminum, to preserve freshness.

"The main problem is recyclability," points out Dermot O'Hare, who led the research. "To recycle [the material], the different layers need to be separated, so while technically it can be recycled at the industrial level, it is not yet economically viable to do so."

Moreover, the fusing together of the polymer and metal layers requires long baking times, which adds up to a large carbon footprint.

In the search for an easier to recycle alternative, the team from Oxford turned to a class of synthetic inorganic clay-like materials called layered double hydroxides (LDHs). These layered metal hydroxides can be exfoliated into dispersions of nanosheets, which can in turn be deposited in thin films onto flexible polymer substrates.

"Because the LDHs we are using are entirely synthetic, unlike some clays that have been used previously for barrier applications,

we can tailor them to be entirely nontoxic, free of any heavy metal traces," says O'Hare. "In terms of the chemistry, this is a breakthrough."

The process starts with Mg<sub>2</sub>Al LDH, which is heated to create a layered double oxide. The oxide is then exfoliated in an amino acid solution to make a translucent gel. Diluting the gel creates a liquid dispersion of Mg<sub>2</sub>Al LDH nanosheets, which can be added to polyvinyl alcohol (PVA) and coated onto a desired substrate such as PET (Fig. 1).

"Our low-energy alternative barrier coating for food packaging eliminates the metallic layers from the polymer film so not only is it much easier to recycle, completely nontoxic, and mechanically stronger than metallized films, it is also transparent and has a lower carbon footprint," explains O'Hare.

The LDH nanosheet layer can be as thin as 100 nm or as thick as 1.8 μm, without affecting the transparency of the substrate film, which could be of significant benefit in food packaging. Most importantly, however, the nanosheets line up parallel to the substrate and form an impenetrable maze – or what is known as a 'tortuous pathway' – for oxygen and water molecules to pass through. This reduces the oxygen and water transmission rate of the LDH-coated PET film to below measurable or very low levels, respectively.

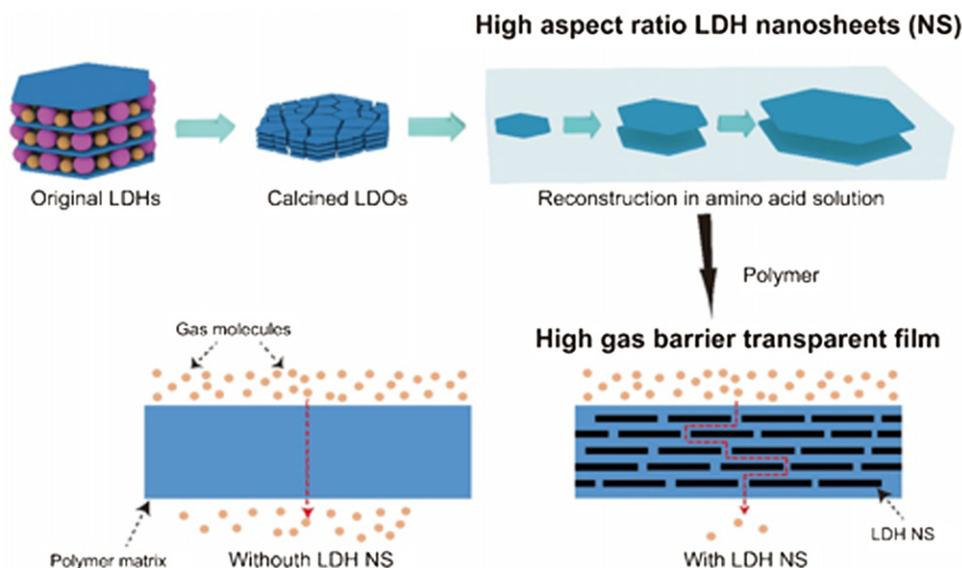


Fig. 1. Schematic shows the fabrication of LDH nanosheets and their use as a barrier layer on a transparent substrate.

“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