StatNano

Nano Science, Technology and Industry Scoreboard

Crafting A “Sponge” for Adsorbing and Desorbing Gas Molecules

2021-10-18

A group of researchers led by scientists from the RIKEN Center for Emergent Matter Science and the University of Tokyo have created an unusual material—a soft crystal made of molecules known as a catenanes—that behaves in a novel way that could be used in applications such as films that capture carbon dioxide molecules.

A catenane is a type of molecule in which two or more rings interlock, like the rings that magicians use in their tricks, and can slide along each other, creating conformational changes that can give materials interesting properties. These types of molecules are found in nature, where they often act as molecular machines. Up until now, chains of catenanes—known as polycatenanes—have been created, but scientists have never explored three-dimensional crystals made up of these molecules.

The group set to explore this, and created a new material by growing crystals of catenanes and cobalt ions in a solvent. By carefully controlling the arrangements of catenane molecules through the formation of coordination bonds with the cobalt ions, they thought they might be able to create a three-dimensional network consisting almost solely of the catenanes, which work together to create novel functions.

The researchers then used single-crystal X-ray diffraction to examine the structure of the soft crystal.

While the researchers were essentially exploring what types of properties such materials might have, they were surprised by the results of the analysis. First, in agreement with their expectations, they found that by weight, catenanes made up more than 90 percent of the crystal. Interestingly, they found that it was porous, with holes that could adsorb solvent, or gaseous molecules, and that the pore shape changed as the guest molecules entered or exited the structure.

(Left) The chemical structure of the catenanes that make up the crystal. (Right) the structure of the metal-organic crystal seen in one direction.

In addition, using a technique of nano-indentation to study the mechanical properties, they found that the material deformed easily when pressed mechanically—and that its Young's modulus, an index of the ease with which it deforms, is comparable to that of polypropylene, a plastic used in packaging materials and other uses—and that, surprisingly, it returned to its original shape, without damage, upon removal of the force. Furthermore, when they tried to compress it, they found that it compressed most in a specific direction, and they were able to explain its deformable nature by showing that actually, the rings of the catenane molecules were slipping, allowing the material to compress.

According to Hiroshi Sato, who led the research, "We believe these results could lead to the creation of innovative porous materials that can adsorb and desorb gas molecules such as carbon dioxide simply by pinching and releasing them with our fingers."

The research was published in Nature.

Read the original article on RIKEN.