Synthetic nanotubes lay foundation for new technology: Artificial pores mimic key features of natural pores

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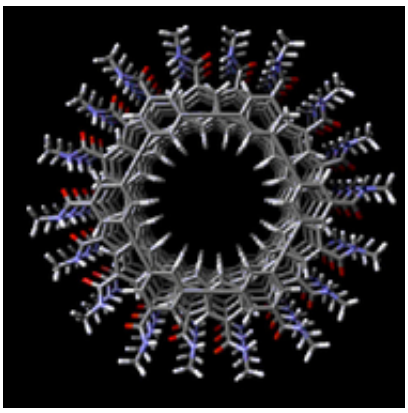

A snapshot of a helical stack of macryocycles generated in the computer simulation.

(Phys.org) -- Scientists have overcome key design hurdles to expand the potential uses of nanopores and nanotubes. The creation of smart nanotubes with selective mass transport opens up a wider range of applications for water purification, chemical separation and fighting disease.

Nanopores and their rolled up version, nanotubes, consist of atoms bonded to each other in a hexagonal pattern to create an array of nanometer-scale openings or channels. This structure creates a filter that can be sized to select which molecules and ions pass into drinking water

or into a cell. The same filter technique can limit the release of chemical by-products from industrial processes.

Successes in making synthetic nanotubes from various materials have been reported previously, but their use has been limited because they degrade in water, the pore size of water-resistant carbon nanotubes is difficult to control, and, more critically, the inability to assemble them into appropriate filters.

An international team of researchers, with help of the Advanced Photon Source at Argonne National Laboratory, have succeeded in overcoming these hurdles by building self-assembling, size-specific nanopores. This new capability enables them to engineer nanotubes for specific functions and use pore size to selectively block specific molecules and ions.

Scientists used groupings of atoms called ridged macrocycles that share a planar hexahenylene ethynylene core that bears six amide side chains. Through a cellular self-assembly process, the macrocycles stack cofacially, or atom on top of atom. Each layer of the macrocycle is held together by bonding among hydrogen atoms in the amide side chains. This alignment creates a uniform pore size regardless of the length of the nanotube. A slight misalignment of even a few macrocycles can alter the pore size and greatly compromise the nanotube's functionality.

"It's the first synthetic nanotube that has a very uniform diameter," said Xiao Cheng Zeng, one of the study's senior authors and an emeritus professor at the University of Nebraska-Lincoln.

The pore sizes can be adjusted to filter molecules and ions according to their size by changing the macroycle size, akin to the way a space can be put into a wedding ring to make it fit tighter. The channels are permeable to water, which aids in the fast transmission of intercellular information. The synthetic nanopores mimic the activity of cellular ion

channels used in the human body. The research lays the foundation for an array of exciting new technology, such as new ways to deliver directly into cells proteins or medicines to fight diseases.

“The idea for this research originated from the biological world, from our hope to mimic biological structures, and we were thrilled by the results,” said Bing Gong, a professor for the University at Buffalo in New York, who led the study. “We have created the first quantitatively confirmed synthetic water channel.”

"Self-assembling subnanometer pores with unusual mass-transport properties" appears July 17 in the journal *Nature Communications*.

“This is the first demonstration of molecular engineering to create an array of nanotubes of uniform pore size that allows ion-selective transport for a specific function,” said Zhonghou Cai, a scientist with the Advanced Photon Source. A high-energy X-ray beam from a light source, such as the APS, was the only way to confirm computer simulations and test the synthesized nanotube’s uniformity layer by layer. “You don’t often get to work on something this exciting.”

Provided by Argonne National Laboratory