Researchers use carbon nanotubes for molecular transport

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Molecular transport across cellular membranes is essential to many of life's processes, for example electrical signaling in nerves, muscles and synapses.

In biological systems, the membranes often contain a slippery inner surface with selective filter regions made up of specialized protein channels of sub-nanometer size. These pores regulate cellular traffic, allowing some of the smallest molecules in the world to traverse the membrane extremely quickly, while at the same time rejecting other small molecules and ions.

Researchers at Lawrence Livermore National Laboratory are mimicking that process with manmade carbon nanotube membranes, which have pores that are 100,000 times smaller than a human hair, and were able to determine the rejection mechanism within the pores.

"Hydrophobic, narrow diameter carbon nanotubes can provide a simplified model of membrane channels by reproducing these critical features in a simpler and more robust platform," said Olgica Bakajin, who led the LLNL team whose study appeared in the June 6 online edition of the journal *Proceedings of the National Academy of Sciences*.

In the initial discovery, reported in the May 19, 2006 issue of the journal *Science*, the LLNL team found that water molecules in a carbon nanotube move fast and do not stick to the nanotube's super smooth surface, much like water moves through biological channels. The water molecules travel in chains - because they interact with each other strongly via hydrogen bonds.

"You can visualize it as mini-freight trains of chain-bonded water molecules flying at high speed through a narrow nanotube tunnel," said Hyung Gyu Park, an LLNL postdoctoral researcher and a team member.

One of the most promising applications for carbon nanotube membranes is sea water desalination. These membranes will some day be able to replace conventional membranes and greatly reduce energy use for desalination.

In the recent study, the researchers wanted to find out if the membranes with 1.6 nanometer (nm) pores reject ions that make up common salts. In fact, the pores did reject the ions and the team was able to understand the rejection mechanism.

"Our study showed that pores with a diameter of 1.6nm on the average, the salts get rejected due to the charge at the ends of the carbon nanotubes," said Francesco Fornasiero, an LLNL postdoctoral researcher, team member and the study's first author.

Fast flow through carbon nanotube pores makes nanotube membranes more permeable than other membranes with the same pore sizes. Yet, just like conventional membranes, nanotube membranes exclude ions and other particles due to a combination of small pore size and pore charge effects.

"While carbon nanotube membranes can achieve similar rejection as membranes with similarly sized pores, they will provide considerably higher permeability, which makes them potentially much more efficient than the current generation of membranes," said Aleksandr Noy, a senior member of the LLNL team.

Researchers will be able to build better membranes when they can independently change pore diameter, charge and material that fills gaps between carbon nanotubes.

Source: Lawrence Livermore National Laboratory