

Scientists observe single ions moving through tiny carbon-nanotube channel

EurekAlert

CAMBRIDGE, Mass. — For the first time, a team of MIT chemical engineers has observed single ions marching through a tiny carbon-nanotube channel. Such channels could be used as extremely sensitive detectors or as part of a new water-desalination system. They could also allow scientists to study chemical reactions at the single-molecule level.

Carbon nanotubes — tiny, hollow cylinders whose walls are lattices of carbon atoms — are about 10,000 times thinner than a human hair. Since their discovery nearly 20 years ago, researchers have experimented with them as batteries, transistors, sensors and solar cells, among other applications.

In the Sept. 10 issue of *Science*, MIT researchers report that charged molecules, such as the sodium and chloride ions that form when salt is dissolved in water, can not only flow rapidly through carbon nanotubes, but also can, under some conditions, do so one at a time, like people taking turns crossing a bridge. The research was led by associate professor Michael Strano.

The new system allows passage of much smaller molecules, over greater distances (up to half a millimeter), than any existing nanochannel. Currently, the most commonly studied nanochannel is a silicon nanopore, made by drilling a hole through a silicon membrane. However, these channels are much shorter than the new nanotube channels (the nanotubes are about 20,000 times longer), so they only permit passage of large molecules such as DNA or polymers — anything smaller would move too quickly to be detected.

Strano and his co-authors — recent PhD recipient Chang Young Lee, graduate student Wonjoon Choi and postdoctoral associate Jae-Hee Han — built their new nanochannel by growing a nanotube across a one-centimeter-by-one-centimeter plate, connecting two water reservoirs. Each reservoir contains an electrode, one positive and one negative. Because electricity can flow only if protons — positively charged hydrogen ions, which make up the electric current — can travel from one electrode to the other, the researchers can easily determine whether ions are traveling through the nanotube.

They found that protons do flow steadily across the nanotube, carrying an electric current. Protons flow easily through the nanochannel because they are so small, but the researchers observed that other positively charged ions, such as sodium, can also get through but only if enough electric field is applied. Sodium ions are much larger than protons, so they take longer to cross once they enter. While they travel across the channel, they block protons from flowing, leading to a brief disruption in current known as the Coulter effect.

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Published on Electronic Component News (<http://www.ecnmag.com>)

Strano believes that the channels allow only positively charged ions to flow through them because the ends of the tubes contain negative charges, which attract positive ions. However, he plans to build channels that attract negative ions by adding positive charges to the tube.

Once the researchers have these two types of channels, they hope to embed them in a membrane that could also be used for water desalination. More than 97 percent of Earth's water is in the oceans, but that vast reservoir is undrinkable unless the salt is removed. The current desalination methods, distillation and reverse osmosis, are expensive and require lots of energy. So a nanotube membrane that allows both sodium and chloride ions (which are negatively charged) to flow out of seawater could become a cheaper way to desalinate water.

This study marks the first time that individual ions dissolved in water have been observed at room temperature. This means the nanochannels could also detect impurities, such as arsenic or mercury, in drinking water. (Ions can be identified by how long it takes them to cross the channel, which depends on their size). "If a single arsenic ion is floating in solution, you could detect it," says Strano.

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