The presence of oxygen on carbon nanotubes enhances interaction with ammonia

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Discovery could help in the development of sensors against chemical threats

Single-walled carbon nanotubes (SWNTs), which could play an important role in developing sensors against chemical threats, have enhanced interaction with ammonia because of the presence of oxygen groups on the nanotubes, researchers at Temple University have discovered.

Their findings, "Sensitivity of Ammonia Interaction with Single-Walled Carbon Nanotube Bundles to the Presence of Defect Sites and Functionalities," are reported online July 8 in the Journal of the American Chemical Society.

Eric Borguet, Ph.D., associate professor of chemistry at Temple and the study's lead author, said scientists have shown that in using nanotubes for sensors, their conductivity can be changed by the presence of ammonia.

"Theorists have tried for a long time to explain this interaction, and their calculations have typically shown that the interaction between the carbon nanotubes and ammonia is very weak, and in fact, very few ammonia molecules would stick to the nanotubes at room temperature," said Borguet.

But, he said, the theorists are studying pure nanotubes--often referred to as "perfect" nanotubes--with no oxygen.

Through the use of infrared spectroscopy, Borguet and his collaborators believe they are the first to reveal that the SWNT purification process, which introduces oxygen to the nanotubes, changes the interaction with chemical species such as ammonia.

"It is no longer pure carbon; there are oxygen-containing groups on the purified nanotubes," said Borguet. "And it is the presence of those groups that enhances the interaction between the nanotubes and the ammonia molecules at any temperature.

"We take the nanotubes and heat them up to 500 degrees Kelvin and then cool them down to 94 degrees Kelvin, and we see ammonia sticking, but as we go higher and higher in temperature, the ammonia signal is going down," said Borguet.

"One of the things that is happening as we heat to higher and higher temperatures is we are driving off the oxygen-containing functionality," added Borguet. "Once that oxygen-containing functionality is gone, 'poof,' the ability of the ammonia to stick is gone. But if we re-expose the SWNTs to room temperature and ambient air, the ability to interact comes back."

Borguet said the researchers were not able to detect the oxygen after exposure to air, so the nanotubes may be reoxidizing at a very small level.

He also emphasized that although they are unable to detect the ammonia sticking to the SWNTs at higher temperatures, the lack of detection may be the result of using the infrared spectroscopy technique.

"There may be another technique with a higher sensitivity that can detect the presence of ammonia," Borguet said. "We can't say there is no ammonia, but if there is, it is below our group's detection capability."

Borguet said that this discovery of oxygen impacting the interaction of ammonia with the SWNTs could eventually be important in developing small sensors for Homeland Security.

"Ultimately, you'd like to make a chemical nose, a device that can distinguish between chemicals which might have different hazards associated with them," he said. "You'd like to be able to identify the chemicals and what type of concentration might be present.

"These finding are a step in the right direction," Borguet added. "This could be an important discovery because theorists have all been calculating using 'perfect' nanotubes, but the experiments are not being carried out on 'perfect' nanotubes.

"The theorists can no longer ignore that there is going to be oxygen-containing functionality when looking at the effects of these nanotubes in the future."

Source: Temple University

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