Modifications render carbon nanotubes nontoxic

October 26 2005

In follow-on work to last year's groundbreaking toxicological study on water-soluble buckyballs, researchers at Rice University's Center for Biological and Environmental Nanotechnology (CBEN) find that water-soluble carbon nanotubes are significantly less toxic to begin with. Moreover, the research finds that nanotubes, like buckyballs, can be rendered nontoxic with minor chemical modifications.

The findings come from the first toxicological studies of water-soluble carbon nanotubes. The study, which is available online, will be published in an upcoming issue of the journal *Toxicology Letters*.

The research is a continuation of CBEN's pioneering efforts to both identify and mitigate potential nanotechnology risks.

"Carbon nanotubes are high-profile nanoparticles that are under consideration for dozens of applications in materials science, electronics and medical imaging," said CBEN Director Vicki Colvin, the lead researcher on the project. "For medical applications, it is reassuring to see that the cytotoxicity of nanotubes is low and can be further reduced with simple chemical changes."

Research has been conducted on the toxicity of carbon nanotubes, but CBEN's is the first to examine the cytotoxicity of water-soluble forms of the hollow carbon molecules. In their native state, carbon nanotubes are insoluble, meaning they are incompatible with the water-based environment of living systems. Solubility is a key issue for medical applications, and researchers at Rice and elsewhere have developed processing methods that render nanotubes soluble. In particular, scientists are keen to exploit the fluorescent properties of carbon nanotubes for medical diagnostics.

Nanotubes are long, hollow molecules of pure carbon with walls just one atom thick. They are related to buckyballs, tiny spheres of pure carbon that are about the same diameter.

In previous studies with buckyballs, CBEN found that even minor surface modifications could dramatically reduce cytotoxicity. The nanotube study found similar results. In both cases, the researchers identified specific alterations that reduce toxicity.

Cytotoxicity refers to toxic effects on individual cells. In cytotoxicological studies, identical cell cultures are exposed to various forms and concentrations of toxins. In order to compare the toxicity of different compounds, scientists look for the concentration -- typically measured in parts per million or parts per billion -- of materials that lead to the death of 50 percent of the cells in a culture within 48 hours.

In the current study, CBEN researchers exposed skin cell cultures to varying doses of four types of water-soluble single-walled carbon nanotubes, or SWNTs. The four included pure, undecorated SWNTs suspended in soapy solution and three forms of nanotubes that were rendered soluble via the attachment of the chemical subgroups hydrogen sulfite, sodium sulfite and carboxylic acid.

The cytotoxicity of undecorated SWNTs was 200 parts per billion, which compares to the level of 20 parts per billion identified last year for undecorated buckyballs.

The modified nanotubes were non-cytotoxic. While cell death did increase with dose concentration, cell death never exceeded 50 percent for these compounds, which were each tested to a level of 2,000 parts per million. Just as with buckyballs, CBEN found that higher degrees of surface modification led to lower toxicity for SWNTs.

"We now have two studies on carbon nanoparticles that show us how to make them dramatically less cytotoxic," said CBEN Executive Director Kevin Ausman, a co-author of the study. "In both cases, it's the same answer: change the surfaces. This is an important demonstration that there are general trends in biological responses to nanoparticles."

Co-authors on the paper include graduate students Christie Sayes, Feng Liang, Jared Hudson, Jonathan Beach and Condell Doyle; undergraduate Joe Mendez; research scientists Wenhua Guo and Valerie Moore; Professor of Chemistry Edward Billups; and Jennifer West, the Isabel C. Cameron Professor of Bioengineering, professor of chemical and biomolecular engineering, and director of the Institute of Biosciences and Bioengineering.

Source: Rice University