



## Radiation Protection Using Single-Wall Carbon Nanotube Derivatives

**Stress mitigation protects DNA and other healthy cell components from the effects of radiation therapy or radiation-containing weapons.**

*Lyndon B. Johnson Space Center, Houston, Texas*

This invention is a means of radiation protection, or cellular oxidative stress mitigation, via a sequence of quenching radical species using nano-engineered scaffolds, specifically single-wall carbon nanotubes (SWNTs) and their derivatives. The material can be used as a means of radiation protection by reducing the number of free radicals within, or nearby, organelles, cells, tissue, organs, or living organisms, thereby reducing the risk of damage to DNA and other cellular components (i.e., RNA, mitochondria, membranes, etc.) that can lead to chronic and/or acute pathologies, including but not limited to cancer, cardiovascular disease, immuno-suppression, and disorders of the central nervous system. In addition, this innovation could be used as a prophylactic or antidote for accidental radiation exposure, during high-altitude or space travel where exposure to radiation is anticipated, or to protect from exposure from deliberate terrorist or wartime use of radiation-containing weapons.

BHA and BHT are well-known food preservatives that are excellent radical scavengers. These compounds, among others, attached to SWNTs make excellent radical traps. The 4-(2-aminoethyl)-

2,6-bis(1,1-dimethylethyl)phenol (amino-BHT, compound 3, Scheme 1) groups are associated with nano-engineering materials. The amino-BHT groups can be associated with SWNTs that have carboxylic acid groups via acid-base association, or via covalent attachment. The SWNTs can also have poly(ethylene glycol) (PEG) chains associated with them to enhance the solubility of the nano-engineered materials in water and buffered systems. Likewise, 4-(2-carboxyethyl)-2,6-bis(1,1-dimethylethyl)phenol (carboxy-BHT, compound 4, Scheme 2) can be associated with aminated SWNTs (i.e., SWNTs that are carboxylated, then aminated via interaction with poly(ethylene imine), again via acid base association.

One idea is to attach 2,6-di(*tert*-butyl)phenols (BHT and BHA analogs) to SWNTs, and to use these as delivery agents to quench large amounts of radicals that can be established in a cell due to oxidative stress or radiation-induced pathways. The *tert*-butyl groups are most properly named as 1,1-dimethylethyl moieties. Many other radical scavengers can be appended to the sidewalls of water-soluble SWNTs via acid-base, covalent or non-covalent ( $\pi$ - $\pi$  interactions

of Van der Waals interactions) functionalized protocols. In some cases, the parent pluronic-wrapped SWNT can show efficacy in this reaction as well. Two other known therapeutic radical scavengers include Lavendustin B and Amifostin. One skilled in the art can think of several permutations for derivatizing radical scavengers to SWNTs or double-wall nanotubes (DWNTs) for multi-wall nanotubes (MWNTs) where there are three or more walls predominating in a sample.

*This work was done by James M. Tour, Meng Lu, Rebecca Lucente-Schultz, Ashley Leonard, Condell Dewayne Doyle, Dimitry V. Kosynkin, and Brandi Katherine Price of Rice University for Johnson Space Center.*

*In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:*

*Rice University  
Office of Technology Transfer MS-705  
P.O. Box 1892  
Houston, TX 77251-1892  
Phone No.: (713) 348-6188  
E-mail: [techtran@rice.edu](mailto:techtran@rice.edu)*

*Refer to MSC-24383-1, volume and number of this NASA Tech Briefs issue, and the page number.*

## PMA-PhyloChip DNA Microarray To Elucidate Viable Microbial Community Structure

**This technology has applications in pharmaceutical and medical equipment manufacturing, and food processing.**

*NASA's Jet Propulsion Laboratory, Pasadena, California*

Since the Viking missions in the mid-1970s, traditional culture-based methods have been used for microbial enumeration by various NASA programs. Viable microbes are of particular concern for spacecraft cleanliness, for forward contamination of extrater-

restrial bodies (proliferation of microbes), and for crew health/safety (viable pathogenic microbes). However, a "true" estimation of viable microbial population and differentiation from their dead cells using the most sensitive molecular methods is a chal-

lenge, because of the stability of DNA from dead cells.

The goal of this research is to evaluate a rapid and sensitive microbial detection concept that will selectively estimate viable microbes. Nucleic acid amplification approaches such as the