Nanotechnology: Carbon Nanotube and Thiol Tethered ssDNA Interactions on Gold to Improve Nanomanufacturing

NIST is developing Raman spectroscopy and atomic force microscopy to measure the affect that pretreatment of carbon natotubes (CNT) with single stranded DNA has on the dispersion of these materials used in nanosensor manufacturing. The work is being conducted to better understand how to appropriately disperse CNTs during nanosensor production and eliminate associated measurement inconsistencies caused by polydispersity. The work is expected to enable new innovation in the medical diagnostic and homeland security market sectors.

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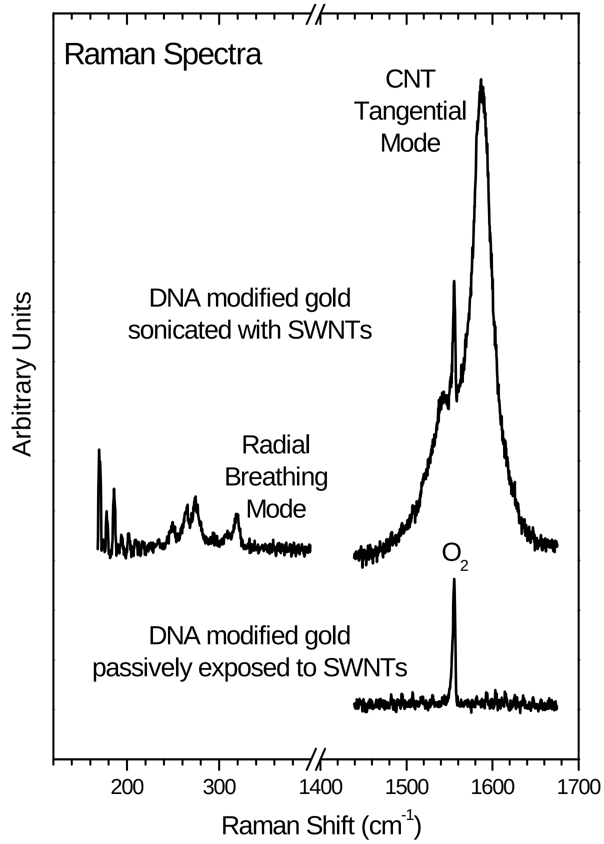
Single wall carbon nanotubes (SWNTs) are promising materials for chemical and biological sensing applications. Several studies have shown that the electrical conductivity of SWNTs is extremely sensitive to changes in the local chemical environment, a property most likely resulting from the fact that all carbon atoms of SWNTs reside at the surface. Some researchers have reported near single-molecule detection capabilities with SWNT-derived conductivity sensors. In contrast, other groups have reported much more modest sensitivities. These discrepancies along with other irreproducible behaviors that have plagued SWNT sensing studies are most likely due to the inherent polydispersity (i.e., metallic and semiconducting) of SWNT samples and the difficulty in precisely assembling SWNTs in sensing devices. One promising approach to these major challenges is to use single-stranded DNA (ssDNA) to disperse SWNTs as pioneered by Zheng and coworkers at Dupont. The ssDNA wraps around the SWNT and imparts a negative charge on the DNA/SWNT hybrid material that allows for rudimentary purification of metallic vs. semiconducting SWNTs by anion-exchange chromatography. Our approach is to build from this scientific discovery a method of purifying SWNTs using a DNA modified solid support.

NIST is helping industry understand how DNA modification of carbon nanotubes can be used in the manufacturing of nanosensors.

Our approach is to build from solution based ssDNA-SWNT dispersion technology a method of purifying SWNTs using a DNA modified solid support. We postulate that the DNA on the solid support will wrap around the SWNTs with sonication in the same manner as free DNA reported previously. The advantage of using DNA that is attached to a solid support is that once the DNA-SWNT hybrids form, we will be able to achieve a primary separation by removing the solid support from the free DNA / SWNT solution. The solid support also serves as a platform for characterization of the DNA-SWNTs.



The adsorption of SWNTs to DNA modified gold surfaces were examined using Raman spectroscopy and atomic force microscopy (AFM) with and without sonication. It was found that the SWNTs do not adsorb to DNA modified gold surfaces without the aid of sonication as evaluated by Raman spectroscopy; CNTs have high Raman cross sections and distinct Raman scattering signatures which enable definitive confirmation of the presence or absence of CNTs on a surface. SWNTs were found to interact with DNA modified gold surfaces with sonication as evidenced by Raman scattering experiments and AFM. Raman spectra confirm the presence of CNTs on the surface with intensities in both the tangential mode (strong) and radial breathing mode (weaker) regions expected for CNTs. Multiple peaks present in the radial breathing mode region indicate that there is a distribution in diameters of the SWNTs. AFM images taken of DNA modified surfaces after sonication with SWNTs show the presence of nanotube like structures not seen prior to sonication. The measured dimensions of nanotube features in AFM images suggest that the SWNTs are present as single nanotubes and in bundles.

SWNTs were successfully attached to DNA modified gold surfaces through sonication. The selectivity of this process is still under investigation. These findings can also be applied to the directed deposition of SWNTs to DNA modified surfaces.

Future Directions: We hope to explore further the interaction of SWNTs with various DNA compositions, sonication times, and power levels to optimize the specificity of the DNA-SWNT interaction for specific populations (size and electronic character) of nanotubes. Other variables that may be explored will be the length, and the density of the DNA sequences on the solid support surface.

Outputs: These results were received favorably at the AVS 53rd International Symposium [Zangmeister, R. A.; Maslar, J.; Kushmerick, J. " Carbon Nanotube and Thiol Tethered ssDNA Interactions on Gold," *AVS 53rd International Symposium and Exhibition* San Francisco, Nov. 12 - Nov. 17, 2006], and are being prepared for submission to a peer-reviewed journal.

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