Nanosensor Development: Self-assembly of DNA-Wrapped Carbon Nanotubes for Sensing Applications

NIST scientists are developing nanosensor measurement devices using single walled carbon nanotubes coated with single stranded DNA. The DNA serves as a dispersant during manufacturing and is being tested to determine the degree to which it provides for a more consistent layering of the CNTs on the nanosensor surface. The work is expected to enable new innovation in the medical diagnostic and homeland security market sectors.

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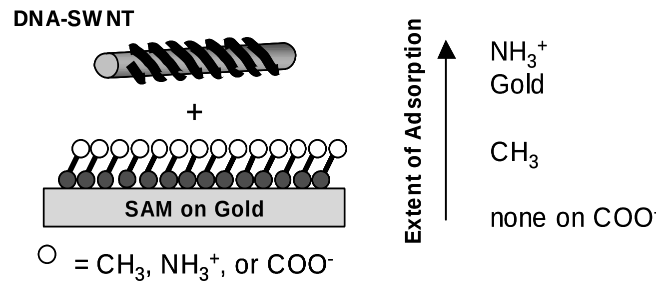
Carbon nanotubes (CNTs) are promising materials for chemical and biological measurement and sensing technology applications. Several studies have shown that the electrical conductivity of CNTs is extremely sensitive to changes in the local chemical environment, a property most likely resulting from the fact that all carbon atoms of CNTs reside at the surface. Some researchers have reported near single molecule detection capabilities with CNT-derived conductivity sensors. In contrast, other groups have reported much more modest sensitivities. These discrepancies along with other irreproducible behaviors that have plagued CNT sensing studies are most likely due to the inherent polydispersity (i.e., metallic and semiconducting) of CNT samples and the difficulty in precisely positioning and assembling CNTs in sensing devices. One promising approach to these major challenges is to use single-stranded DNA (ssDNA) to disperse single walled nanotubes (SWNTs) as pioneered by Zheng and coworkers at Dupont. We postulate that the ssDNA moieties will also allow for controlled placement of SWNTs onto nanodevice test structures based on ssDNA-surface interactions.

NIST scientists are developing new nanomanufacturing technologies for higher consistency nanosensors using ssDNA coated carbon nanotubes.

Our approach is to study the adsorption of DNA-SWNT hybrid materials on model self-assembled monolayer (SAM) modified surfaces to determine which chemical functional groups can be used to anchor DNA-SWNTs to surfaces. The long-term goal is to use organic monolayers to direct the placement of SWNTs with nanometer resolution to fabricate conductometric-based sensing devices. Reflection absorption FT-IR (RAIRS), micro-Raman spectroscopy, and secondary ion mass spectrometry (SIMS) imaging are used to determine whether DNA-SWNTs can be differentially deposited based on affinity towards chemically patterned surfaces.

We have determined that DNA-SWNT hybrid materials adsorb to model self-assembled monolayer (SAM) surfaces with the affinity order towards terminal chemical functionalities: NH_3^+ > gold >> CH_3, and no affinity towards COO^-. The attraction between the DNA-SWNT hybrid material and these surfaces was anticipated based on prior knowledge of the interactions of ssDNA on model surfaces. The negative charge associated with the DNA wrapping influences adsorption of the DNA-SWNT material to positively charged amine terminated surfaces due to electrostatic interactions. Similarly, the adsorption of the hybrid material on bare gold surfaces is likely due to the chemisorption of the bases associated with the DNA wrapping on gold surfaces. The minimal attraction of the DNA-SWNT hybrid material to neutral surfaces is attributable to weaker hydrophobic interactions.

SIMS analysis of patterned SAM surfaces (alternating NH_3^+/CH_3 grid pattern of ca. 10 µm) that were exposed to solutions of DNA-SWNT materials revealed that DNA-SWNTs do not differentially deposit based on the patterned SAM surface. Large bundles of DNA-SWNT materials were observed on the surface with no commensuration with the underlying chemically patterned surface. This observation suggests that the attraction between DNA-SWNT species may dominate their behavior at the solution surface interface and obstructs patterning of these materials at the micron size scale examined here.



Impact: These studies indicate that organic monolayers can be used to deposit DNA-wrapped SWNTs on surfaces. The DNA wrapping of the DNA-SWNT hybrid appears to be in a chemical environment similar to that of free DNA such that it can adsorb predictably to model SAM surfaces. The affinity towards specific functional groups is not great enough to differentially pattern DNA-SWNTs on a micron size scale.

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