Detection of Biomolecules using the Band-Gap Fluorescence of Single Walled Carbon Nanotubes

Molecular detection using near-infrared light between 0.9 and 1.3 eV has important biomedical applications because of greater tissue penetration and reduced auto-fluorescent background in thick tissue or whole-blood media. Carbon nanotubes have a tunable near-infrared emission that responds to changes in the local dielectric function but remains stable to permanent photobleaching. We report the synthesis and demonstration of several types of solution-phase, near-infrared sensors by functionalizing carbon nanotubes with ligands designed to modulate the fluorescence in response to selective molecular binding. By adsorbing glucose oxidase and ferricyanide ions to the surface of carbon nanotubes, a flux-based β-D-glucose sensor is created. Reaction of glucose at the enzyme ultimately injects charge into the nanotube and modulates the fluorescence via two distinct mechanisms of signal transduction—fluorescence quenching and charge transfer. We also demonstrate the optical detection of specific DNA sequences including single nucleotide polymorphism on the surface of solution suspended single-walled carbon nanotubes (SWNT) through a SWNT band gap fluorescence modulation. Hybridization of a 24-mer oligonucleotide sequence with its complement produces a hypsochromic shift of 2meV, with a detection sensitivity of 6 nM. In another system, the transition of DNA secondary structure from the native B to the Z conformation is shown to modulate the dielectric environment of the single walled carbon nanotube (SWNT) around which it is adsorbed. The SWNT band gap near infrared fluorescence emission energy decreases up to 16 meV for a 30-mer oligonucleotide when the system is exposed to counter-ions that screen the charged backbone. The transition is thermodynamically identical for DNA on and off the nanotube, except that the propagation length of the former is shorter by one-sixth. These changes can be observed in strongly scattering or absorbing media, and we demonstrate optical detection of Hg2+ in whole blood, dye colored water, tissue, and from localized complexes within living mammalian cells. The results demonstrate new opportunities for nanoparticle optical sensors that operate in strongly absorbing media of relevance to medicine or biology.

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Professor Michael S. Strano received is B.S from Polytechnic University in Brooklyn, NY and Ph.D. from the University of Delaware both in Chemical Engineering. He was a post doctoral research fellow at Rice University in the departments of Chemistry and Physics under the guidance of Nobel Laureate Richard Smalley. He joined the faculty at the University of Illinois in 2003, is affiliated with the Bioengineering Department, and a part time faculty member of the Beckman Institute. Michael is the recipient of a 2004 Dupont Young Professor Award, 2004 MIT Technology Review TR100 Award, an NSF CAREER Award (2005), the 2005 Young Investigator Award from the Nanoscale Science and Engineering Forum of the American Institute of Chemical Engineers, recognition from Essential Science Indicators/Web of Science (2005) and the 2006 Coblentz Award for Molecular Spectroscopy.