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Optical Characterization and Applications of Single Walled Carbon Nanotubes

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Recent advances in the dispersion and separation of single walled carbon nanotubes have led to new methods of optical characterization and some novel applications. We find that Raman spectroscopy can be used to probe the aggregation state of single-walled carbon nanotubes in solution or as solids with a range of varying morphologies. Carbon nanotubes experience an orthogonal electronic dispersion when in electrical contact that broadens (from 40 meV to roughly 80 meV) and shifts the interband transition to lower energy (by 60 meV). We show that the magnitude of this shift is dependent on the extent of bundle organization and the inter-nanotube contact area. In the Raman spectrum, aggregation shifts the effective excitation profile and causes peaks to increase or decrease, depending on where the transition lies, relative to the excitation wavelength. The findings are particularly relevant for evaluating nanotube separation processes, where relative peak changes in the Raman spectrum can be confused for selective enrichment. We have also used gel electrophoresis and column chromatography conducted on individually dispersed, ultrasonicated single-walled carbon nanotubes to yield simultaneous separation by tube length and diameter. Electroelution after electrophoresis is shown to produce highly resolved fractions of nanotubes with average lengths between 92 and 435 nm. Separation by diameter is concomitant with length fractionation, and nanotubes that have been cut shortest also possess the greatest relative enrichments of large-diameter species. The relative quantum yield decreases nonlinearly as the nanotube length becomes shorter. These findings enable new applications of nanotubes as sensors and biomarkers. Particularly, molecular detection using near infrared (n-IR) 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 n-IR emission that responds to changes in the local dielectric function but remains stable to permanent photobleaching. We report the synthesis and successful testing of solution phase, near-infrared sensors, with β-D-glucose sensing as a model system, using single walled carbon nanotubes that modulate their emission in response to the adsorption of specific biomolecules. New types of non-covalent functionalization using electron withdrawing molecules are shown to provide sites for transferring electrons in and out of the nanotube. We also show two distinct mechanisms of signal transduction – fluorescence quenching and charge transfer. The results demonstrate new opportunities for nanoparticle optical sensors that operate in strongly absorbing media of relevance to medicine or biology.