Carbon Nanotube Suspensions, Dispersions, & Composites

by

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ABSTRACT

Carbon Nanotubes (CNTs) are amazing structures that hold the potential to revolutionize many areas of scientific research. CNTs can be behave both as semiconductors and metals, can be grown in highly ordered arrays and patterns or in random orientation, and can be comprised of one graphene cylinder (single wall nanotube, SWNT) or several concentric graphene cylinders (multi-wall nanotube, MWNT). Although these structures are usually only a few nanometers wide, they can be grown up to centimeter lengths, and in massive quantities. CNTs can be produced in a variety of processes ranging from repeated combustion of organic material such as dried grass, arc-discharge with graphite electrodes, laser ablation of a graphitic target, to sophisticated chemical vapor deposition (CVD) techniques. CNTs are stronger than steel but lighter than aluminum, and can be more conductive than copper or semiconducting like silicon. This variety of properties has been matched by the wide variety of applications that have been developed for CNTs. Many of these applications have been limited by the inability of researchers to tame these structures, and incorporating CNTs into existing technologies can be exceedingly difficult and prohibitively expensive. It is therefore the aim of the current study to develop strategies for the solution processing and deposition of CNTs and CNT-composites, which will enable the use of CNTs in existing and emerging technologies.

CNTs are not easily suspended in polar solvents and are extremely hydrophobic materials, which has limited much of the solution processing to organic solvents, which also cannot afford high quality dispersions of CNTs. The current study has developed a variety of aqueous CNT solutions that employ surfactants, water-soluble polymers, or both to create suspensions of CNTs. These CNT ‘ink’ solutions were deposited with a variety of techniques that have afforded many interesting structures, both randomly oriented as well as highly ordered CNT architectures, and electroactive devices such as sensors were subsequently produced from these materials. The aqueous solutions developed contain some of the longest CNTs to be suspended in water, which have many benefits for electronic and mechanical properties of the resultant composite materials.

A non-covalent alternative to standard oxidative acid treatment was developed that has an equal ability to suspend CNTs in various solvents, but does not damage the

CNT structure like the covalent functionalization with acids. This strategy has the potential to supplant a widely used method with improved CNT properties, faster and safer processing, and reduced environmental impact of waste materials. The results of this work also suggest that the conductivity of the CNTs may actually be improved by the processing, maximizing the utility if these materials.

Electroactive devices have been successfully developed that exploit the unique electrical and physical properties of CNTs. Sensitive moisture sensors, which can possibly out-perform existing part per million sensors, have been developed with CNT inks and alumina nanoparticles. These sensor materials can be easily deposited on a wide variety of substrate materials and have an increased resistance to fouling compared to mesoporous sensors currently available. Electric double-layer supercapacitors based on novel cellulose-CNT composites have also been developed, and have commercially viable capacitance values, which make them a competitive technology with applications such as cell phones, computers, hand-held electronics, and possibly even electric automobiles. These supercapacitors employ less hazardous materials than competing technologies, and the ease of production of these devices could enable large-scale production of these materials.