Attractive nanotubes for composites

NANOTECHNOLOGY

Polymer crosslinking or the interaction of nanoparticles to form clusters is described statistically by percolation theory. The percolation threshold is the number of individual units – polymer molecules or nanoparticles – required to produce an infinite network or cluster of connected particles. The threshold is a critical issue in producing conductive composites by dispersing conductive particles in an insulating matrix for use in films, coatings, and paints.

One way to reduce the percolation threshold is to use rod-like particles instead of spherical ones, since rods interact to form networks at lower concentrations. Making the rod-like particles interact more strongly could further reduce the threshold.

Researchers at France's Centre de Recherche Paul Pascal in Bordeaux have used a surfactant-based approach to strengthen the interaction between single-walled carbon nanotubes (SWNTs) [Vigolo *et al.*, *Science* (2005) **309**, 920).

The ionic surfactant, sodium dodecyl sulfate (SDS), was used to disperse SWNT bundles in water. Because the nanotubes strongly absorb light, optical microscopy can be used to study their aggregation behavior. SDS forms micelles and induces a depletion attraction between the SWNTs. The strength of the attraction is directly proportional to the micelle concentration and, thus, to the surfactant concentration. The researchers found that increasing the SDS concentration can reduce the percolation threshold by 300%. The lower percolation threshold reduces the amount of expensive SWNTs required in producing conductive composite materials.

John K. Borchardt

Functionalizing nanotubes for solubility

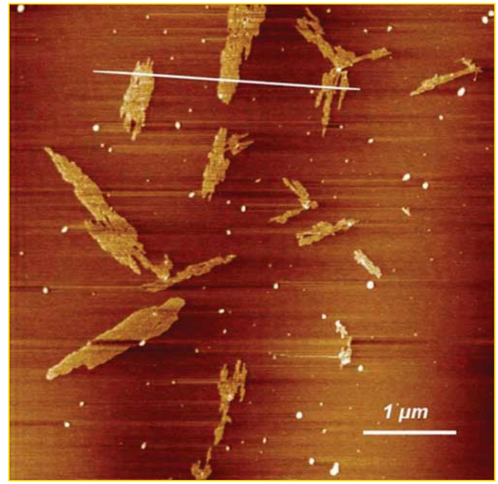
NANOTECHNOLOGY

Ya-Ping Sun and coworkers at Clemson University, NASA Langley Research Center, and Oak Ridge National Laboratory have functionalized single- and multi-walled carbon nanotubes (CNTs) with derivitized polyimides to promote the formation of homogeneous nanotube dispersions [Hill *et al.*, *Macromolecules* (2005) 38 (18), 7670]. Surface defects on the CNTs were oxidized to produce carboxyl groups, which were then esterified with pendant hydroxyl groups of a derivitized polyimide.

The CNTs bearing polyimide chains are soluble in several common organic solvents. Furthermore, the resulting homogeneous dispersions are suitable for wet processing. Results indicate that the functionalized nanotubes are well dispersed in nanocomposites, unlike unfunctionalized CNTs. In addition, CNT electronic properties were little affected by the functionalization.

Aromatic polyimides are high-performance polymers with high thermal stability, low color, flexibility, and processibility. Nanocomposites of CNTs functionalized with aromatic polyimides appear promising for many applications including lightweight aerospace materials.

Hydroxyl moieties are present in many polymers or can be introduced relatively conveniently without significantly changing the rest of the polymer structure. So, this esterification method for functionalizing and solubilizing CNTs could be used with other types of polymers besides polyimides.



Atomic force microscopy image of PVK-functionalized single-walled CNTs. (© 2005 Elsevier.)

Ya-Ping Sun's group has also investigated poly(N-vinyl carbazole), or (PVK), copolymers that contain pendant hydroxyl groups, [Wang *et al.*, *Polymer* (2005) 46 (20), 8634]. Again, the functionalized single-walled CNTs are soluble in common organic solvents. These materials can be wet-cast to form PVK-SWNT thin films that exhibit enhanced charge dissipation under illumination. The broad absorption of SWNTs over visible and near-infrared wavelengths may allow their use as nanoscale dopants for broadband photosensitization.

John K. Borchardt

Nanotube junctions get switched on

NANOTECHNOLOGY

Electrical measurements on Y-shaped carbon nanotube (CNT) junctions have revealed a unique switching behavior that doesn't require an external gate [Bandaru *et al.*, *Nat. Mater.* (2005) **4** (9), 663]. The nanotube Y-junctions, grown by a modified chemical vapor deposition process, demonstrate promise for a new type of logic device.

The research from the University of California, San Diego (UCSD) and Clemson University may provide an alternative to CNT electronic devices based on the traditional metal-oxide field-effect transistor paradigm.

"This is the first time that a transistor-like structure has been fabricated using a branched carbon nanotube," says Prabhakar Bandaru of UCSD. "This discovery represents a new way of thinking about nanoelectronic devices, and I think people interested in creating nanoscale functionality will be inspired to explore the ramifications of these Y-junction elements in greater detail."

The electrical transport through the different branches of the Y-junction was examined. "It's an analogy to the three terminals of a transistor – source, drain, and gate," explains Bandaru. "We wanted to see if there was some intrinsic gating."

Applying a dc voltage to the stem of the 'Y' controls the current through the other two branches. When the dc voltage reaches a certain value, the current in each branch is abruptly switched off.

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