# Nanotubes feel the vibe

**COMPOSITES**

In recent years, carbon nanotube fillers have attracted attention as a possible route to damping vibration in composite materials. Now researchers at Rensselaer Polytechnic Institute have shown that the damping afforded by single-walled carbon nanotube (SWNT)-polymer composites is enhanced at high temperature [Suhr *et al.*, *Nano Lett.* (2006) **6**, 219].

Vibration damping is afforded by interfacial slipping between the nanotubes and the polymer matrix. The large interfacial surface area of nanotubes, together with their high aspect ratio and low mass density, indicates that they should be able to provide significant dissipation of energy with minimal weight penalty. Recent work has shown that this is indeed the case at room temperature.

"Interestingly, [this] mechanism becomes even more efficient at high temperature when interfacial sliding of nanotubes becomes easier to activate," says Nikhil A. Koratkar. The researchers believe this is because the polymer chain backbones become more mobile at higher temperatures, weakening the mechanical bond between the nanotube and the polymer matrix.

High-performance damping materials are necessary in a variety of aerospace, mechanical, and consumer products. "Traditional damping polymers perform poorly at elevated temperatures," says Koratkar. "Our new materials provide excellent damping at high temperatures, suggesting that these nanocomposites show great potential for a variety of applications in aircraft, spacecraft, satellites, automobiles, and even sensors for missile systems." The high cost of SWNTs limits commercial use of such composites for damping, but cheaper multiwalled carbon nanotubes should work just as well.

**Cordelia Sealy**

# Direct route to flexible composites

**COMPOSITES**

A direct method for fabricating carbon nanotube-polymer composites devised by researchers at Northeastern University, Rensselaer Polytechnic Institute, and New Mexico State University yields materials with remarkable properties [Jung *et al.*, *Nano Lett.* (2006) **6**, 413].

The composites are produced in a five-stage process. First, vertically aligned architectures of multiwalled carbon nanotubes (MWNTs) are grown on a patterned Si/$SiO_2$ substrate by thermal chemical vapor deposition. Then a poly(dimethylsiloxane) (PDMS) prepolymer solution is poured over the nanotube structures and the excess removed. The PDMS is then thermally cured at 100°C for 1 h. Self-standing MWNT-PDMS composite films can then be peeled off from the Si substrate. The composites have three remarkable features, according to the researchers. First, the process does not disturb the nanotube architecture, so any size and shape of network can be transferred into the PDMS matrix. Second, the composite is flexible and remains conducting even under extreme tensile and compressive strains. Finally, the composites show field-emission behavior because mutual screening is suppressed when the nanotubes are embedded in the PDMS. "These structures are electromechanically robust, extremely flexible, and transferable, and therefore hold the potential for applications in diverse multifunctional flexible devices," says Yung Joon Jung of Northeastern. The MWNT-PDMS composites could be used as strain gauges, tactile and gas sensors, and as flexible field emitters with some of the best field-emission properties reported to date. Devices fabricated from the composite can operate at high current densities and low voltages because of large field-enhancement factors and low turn-on fields.

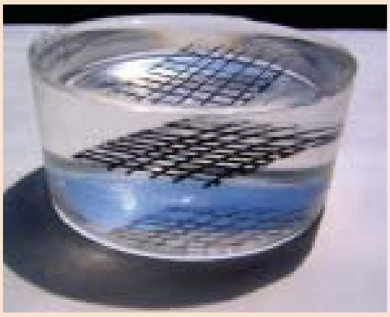

*Photo of aligned nanotube structures (black) in transparent PDMS matrix. (© 2006 Reproduced with permission from American Chemical Society.)*

"Applications in thermal management, gas sensors, and portable display devices are under investigation," says Jung. The composites are also of interest for next generation interconnects and vertical interconnect assemblies. "We believe that our work reflects significant progress in fabricating ordered carbon nanotube-polymer composite systems," he says.

Cordelia Sealy

# Nanotubes play supporting role in composites

**COMPOSITES**

Carbon nanotubes are well known to improve the strength of polymer and ceramic composites, but the results have been less conclusive for metal composites. Now, researchers believe that they have the first conclusive proof that carbon nanotubes do enhance the yield strength and hardness of a metal composite [Goyal *et al.*, *J. Mater. Res.* (2006) **21**, 522].

"Our process involves the growth of single-walled carbon nanotubes (SWNTs) directly in an Fe matrix with fine-scale porosity containing incorporated nano-sized Co and Mo catalyst particles, to form a near final shape nanocomposite," explains Frank J. Owens of the US Army's Development and Engineering Center at Picatinny, New Jersey. He and coworkers at the New Jersey Institute of Technology used a chemical vapor deposition process at 700°C and a carbon monoxide source to produce the composites. Just 2.2 vol.% SWNTs produced a 50% increase in mechanical yield strength compared with a similarly treated Fe sample without nanotubes. The work hardening coefficient also shows an increase of ~240%. Examination with field-emission scanning and transmission electron microscopy reveals bundles of SWNTs well-dispersed in the metal matrix. The nanotube 'ropes' span the cavities present in the porous metal structure and it is this that the researchers believe accounts for the improvement in strength. "We believe that this is due to the direct growth process used, which formed a composite containing damage-free, virgin nanotubes bridging (and thus supporting) the Fe particles," says Owens. Increasing the nanotube loading in the composite by optimizing the growth process and controlling porosity in the Fe matrix could lead to even greater improvement in mechanical strength.

"We plan to scale up the process using chemical vapor infiltration technologies similar to those used by major aerospace companies to manufacture carbon-carbon composites for aircraft brake pads," Owens told *Materials Today*. "Fe or steel nanocomposites with carbon nanotubes would, if manufacturable cost-effectively, find extensive applications," says Owens.

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