Nanotubes in space

Image NASA

Building multifunctional walls for spacecraft

If humans are ever to travel through deep space they'll need protection against the hazards of space radiation associated with solar flares and cosmic rays. To protect their precious human cargo, spacecraft will need special shields incorporating materials consisting of the lighter elements such as hydrogen, boron, and lithium. However, additional shielding comes at a significant price in the form of extra weight, more fuel and increased flight costs.

In order to maintain low weight while increasing safety, reliability, and functionality, many scientists are suggesting that the body of future spacecraft will need to simultaneously serve multiple functions. In other words, the body will need to provide structural integrity, effective shielding, energy storage and carry an array of sensors.

What material or mix of materials could serve so many different functions? A blend of carbon nanotubes is one future material under consideration because of it's light weight, excellent mechanical properties and it's capacity to store energy. Now researchers from the Department of Electronic Materials Engineering are proposing a variation on this theme – isotopically enriched boron nitride nanotubes.

"Isotopically enriched boron nitride nanotubes have many similar properties to carbon nanotubes," says Dr Ying Chen. "However, they also offer some important advantages as they have better radiation-shielding properties and stronger resistance to oxidation.

"By isotopically enriched we mean the boron nitride has a higher concentration of the isotope boron 10. Normally boron nitride is 80% or more composed of boron 11.

"The isotope boron 10 is an efficient neutron absorber with a very high neutron-capture cross section. Consequently it's widely used as the inner shielding layer inside nuclear reactors.

"We have now demonstrated for the first time that it's possible to produce large quantities of high quality isotopically enriched boron nitride nanotubes using a ball-milling/annealing process."

Dr Chen and colleagues Mrs Jun Yu, Professor Rob Elliman and Dr Mladen Petravic has been refining the ball milling process for preparing boron nitride (BN) nanotubes for many years. It involves grinding down a powder of boron into nanoparticles in a ball mill in which steel balls tumble against each other for hundreds of hours. The fine boron material is then heated in an atmosphere of nitrogen (in the form of ammonia, NH_3).

"To produce isotopically enhanced BN nanotubes (referred to as ^{10}BN nanotubes) you begin by grinding down a powder of the isotope boron 10 (often noted as ^{10}B). Our analysis of the final product shows we can produce BN nanotubes with up to 96% boron 10.

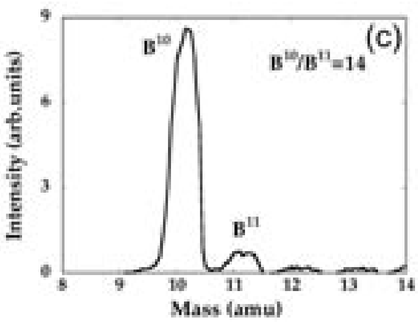
"We found we could produce ^{10}BN nanotubes with different diameters (up to 100 nm) and lengths (up to 100 lm) by varying the growth conditions and atmosphere. For example, nanotubes with a larger diameter (greater than 50 nm) can be produced by annealing at a higher temperature of 1200 °C for a longer period of time.

"The control over the nitriding reaction between the ^{10}B and the NH3 gas is crucial for the formation of thin, cylindrical ^{10}BN nanotubes that contain fewer defects and exhibit stronger mechanical properties than other nanostructures. To avoid the formation of large crystals or thick, bamboo-type nanostructures through fast 3D crystalline growth, the nitriding reactions are carried out at lower temperatures. This can be achieved because of the ball-milling of the boron 10 powders."

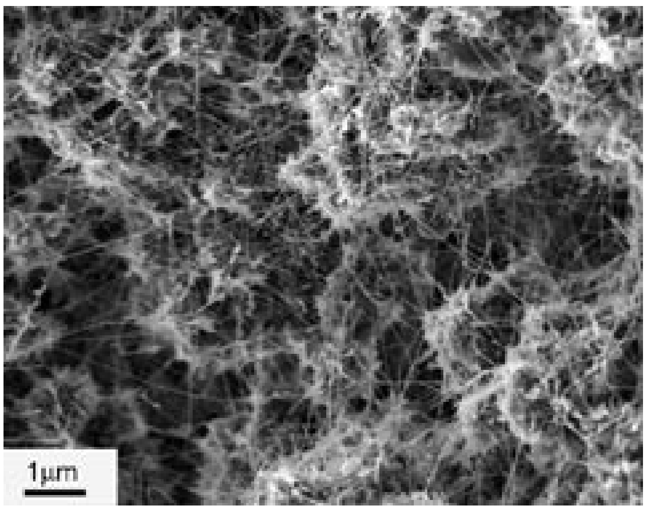
"The ^{10}BN nanotubes are lightweight, with a density of 1.85 g cm−3 and have an excellent resistance to oxidation. They exhibit a high neutron-absorption cross section because of the high content of ^{10}B, as recently determined at ANSTO. The successful production of high yield ^{10}BN nanotubes using a ball-milling/annealing process makes ^{10}BN nanotube samples available in large quantities for space-radiation tests."

And there are many other potential applications for ^{10}BN nanotubes back here on Earth. For example, there is a lot of talk about developing fusion energy to feed an energy-hungry world. One of the major challenges in developing fusion energy on a commercial basis is coming up with materials that can provide shielding from the high neutron fluxes produced by the fusion process. What will be needed is a strong, light weight, cost effective radiation shielding. 10BN nanotubes may just fit the bill. The results have been published in Advanced Materials (18, 2006, 2157).

More info: Ying.Chen@anu.edu.au



Secondary ion mass spectrometry of a sample of ^{10}BN nanotube sample, showing the dominant presence of ^{10}B over ^{11}B.



A scanning electron microscope image of the boron nitride nanotube (enriched with boron 10). They were produced by grinding a powder of the isotope boron 10 in a ball mill for many hours and then heating the crushed powder to around 1100 °C for 6 hours in an atmosphere of ammonia.