Nanotube, heal thyself

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Pound for pound, carbon nanotubes are stronger and lighter than steel, but unlike other materials, the miniscule cylinders of carbon – which are no wider than a strand of DNA – remain remarkably robust even when chunks of their bodies are blasted away with heat or radiation. A new study by Rice University scientists offers the first explanation: tiny blemishes crawl over the skin of the damaged tubes, sewing up larger holes as they go.

"The shape and direction of this imperfection does not change, and it never gets any larger," said lead researcher Boris Yakobson, professor of mechanical engineering and materials science and of chemistry. "We were amazed by it, but upon further study we found a good explanation. The atomic irregularity acts as a kind of safety valve, allowing the nanotube to release excess energy, in much the way that a valve allows steam to escape from a kettle."

The research appears Feb. 16 issue of in *Physical Review Letters*.

Carbon nanotubes are hollow cylinders of pure carbon that measure about a billionth of a meter, or one nanometer, across. They are much longer than they are wide, akin in shape to 100-foot garden hose, and they're 100 times stronger than steel at one-sixth the weight.

The carbon atoms in nanotubes are joined together in six-sided hexagons, so when scientists sketch out the arrangement on paper, nanotubes look something like a rolled up tube of chicken wire. Yakobson's "smart repair machine" is a deformity, a blemish in this

pattern. The blemish consists of a five-sided pentagon joined to a seven-sided heptagon and contains a total of ten atoms. Yakobson, who specializes in using computers to decipher the atomic pecularities of materials, discovered several years ago that mechanically stressed nanotubes – like those being pulled very hard from both ends – are predisposed to develop these 5/7-defects due to the complex interplay of thermodynamic forces at work in the nanotube.

In the latest study, Yakobson, research associate Feng Ding and students examined the effects of other types of stress, including exposure to heat and radiation. The tests confirmed the predisposition of nanotubes to develop the 5/7 blemishes, and they revealed the blemishes' unexpected healing powers.

"The 5/7-blemishes move across the surface of the nanotube like a steamship, giving off puffs of carbon gas," said Ding. "In their wake, the skin of the tube appears pristine, in its characteristic hexagonal arrangement."

Yakobson said the blemishes consume all larger defects, and chug along indefinitely, rearranging atoms and healing the skin of the damaged nanotubes. This explains how nanotubes retain their strength, even when severely damaged. But the healing comes with a price.

"In their role as a safety valve, the 57-steamers give off energy and mass, which is released as pairs of gaseous carbon atoms," Yakobson said. "Since they never change shape or stop moving, they ever so slowly eat away the surface of the nanotube, one pair of atoms at a time."

Yakobson said the 5/7-blemishes turn when they reach the end of the nanotube and return in the opposite direction. In fact, there's only one thing that can stop them: another 5/7 blemish. If two of the blemishes run headlong into one other, they cancel each other out and disappear.

Source: Rice University