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Coming: Superthread From Nanofibers

By **KENNETH CHANG**

Cylindrical molecules of carbon known as nanotubes are the strongest material known, and scientists have now spun yards of thread made of almost 100 percent nanotube.

In the future, these threads could be woven into fabrics that stop bullets or be wound into cables many times as strong as steel.

For now, though, the threads are less than the sum of their nanotube parts. "There are still defects," said Dr. Matteo Pasquali, a professor of chemical engineering at Rice University and head of the research team there that spun the threads.

In the current work, the nanotubes are not packed together tightly, because they are not all the same diameter, and a few contaminating catalyst molecules remain in the final product. The threads have about the same strength as commercial acrylic fibers. That strength is only about 1 percent of what is believed possible — "fairly typical for early lab stage," Dr. Pasquali said.

The findings were published online by the journal *Macromolecules* yesterday.

In 2000, Dr. Philippe Poulin, a scientist at the National Center for Scientific Research in France, developed a technique to spin fibers made of a mix of nanotubes and polymers. This year, researchers at the University of Texas at Dallas and Trinity College in Dublin reported that they had improved Dr. Poulin's technique to produce fibers tougher than any other, natural or synthetic. (Toughness refers to the amount of energy needed to break a fiber.)

Dr. Pasquali's technique eliminates the polymer, the weaker component. Instead, using a method like the one used to make kevlar, the Rice researchers mixed nanotubes with sulfuric acid, producing a thick black paste. The nanotubes gained protons from the acid, giving them a positive charge, which prevents them from clumping together. In the dense solution, the nanotubes, each less than a millionth of an inch wide and less than a thousandth of an inch long, lined up in the same direction, like logs floating down a river.

The researchers then squeezed the paste from a syringe and removed the sulfuric acid, leaving a black nanotube thread the thickness of a human hair. Pure nanotube threads could turn out to be stronger than the polymer-nanotube composites, and engineers should be able to take better advantage of their extraordinary electronic properties in a pure nanotube fiber, Dr. Pasquali said.

Nanotubes can behave either as conductors like copper or as semiconductors like silicon. Physicists at the University of Maryland reported last week in the journal *Nano Letters* that the semiconducting versions of nanotubes outperformed any known semiconductor, building hopes that they will be used in computer chips.