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Superstrong Carbon-Nanotube Fibers

A new process could make nanotube fibers that are strong enough to stop bullets.

By Mason Inman

Carbon nanotubes spun to form long yarnlike fibers could outperform even the strongest bullet-proof materials on the market, but turning nanotubes into such materials has proved to be a challenge. Now researchers say that they have improved the method of making the fibers: they can pull them from a hot furnace faster, make the nanotubes line up better, and vastly improve their strength. While the carbon-nanotube fibers can still be made only in small batches--and only in short lengths, experts say--the fibers show great promise for ultrastrong, resilient materials, with possible applications from body armor to oil drilling.

Carbon nanotubes are pipelike carbon molecules with walls just one atom thick. They are extremely strong, electrically conductive--and hard to make reliably. Many research groups have been toiling to create longer carbon nanotubes and build them into longer strands that could be used for tough fabrics, and even efficient power lines. (See "10 Emerging Technologies (http://www.technologyreview.com/read_article.aspx?ch=infotech&sc=&id=14407&pg=2) .")

Alan Windle, a professor of materials science at the University of Cambridge, in England, made and tested the new nanotube fibers along with researchers at the Natick Soldier Research Development Center, in Massachusetts. Windle and his colleagues tugged on the nanotube fibers, finding that the weaker ones snapped at stresses around one gigapascal, making them comparable to steel, gram for gram.

The better-performing carbon-nanotube fibers broke at around six gigapascals, beating the strengths that manufacturers report for materials used in bullet-proof vests, such as Kevlar. These nanotube fibers matched the highest reported strengths for a couple of the strongest commercially available fibers, Zylon and Dyneema, also used in bullet-proof vests. A lone, extremely strong nanotube fiber was off the charts, reaching nine gigapascals of stress--far beyond any other reported material--before breaking. Earlier work with carbon nanotubes has produced fibers that withstand at most three gigapascals.

"We're pleased with the results, but I wouldn't say we're surprised," Windle says. "It's known that the properties of individual nanotubes are still five times better." He adds, "This makes me optimistic. There's still a huge amount of room for improvement."

To make the fibers, the researchers used a method pioneered by Windle's group in 2004 in which a furnace vaporizes carbon and blows out a stream of nanotubes. When these carbon nanotubes are captured in midair and spun around a spool, they form a fiber composed of billions of the molecules aligned along the length of the nanotube.

By tweaking the temperature of the furnace and adjusting how quickly they wind up the fiber, the researchers optimized the process, making fibers 0.3 times stronger than those that other groups have made. The researchers report that the improvement is largely because with faster winding, the nanotubes align better and pack together more tightly. They also added a step to make the fibers more dense. The team ran the fibers through acetone gas, which condensed on the fibers, forming a liquid. "There's a surface tension effect that pulls the nanotubes together," which boosts their strength, Windle says.

"The most up-front application is for body armor," he says. "It looks promising compared to commercially available fibers." But whether or not it will work for body armor "no one will really know until we make enough fiber to make a fabric and shoot a bullet at it," Windle says. A recent computer modeling study suggests that

bullets would bounce off a carbon-nanotube fabric just six layers thick.

Edwin Thomas, a professor of materials science and engineering at MIT, says that if tests showed that such fabric really did repel bullets, "you've got a showstopper, and it's going to be in body armor soon." But materials often don't cope well when hit with sudden forces as opposed to slower tugging, he adds. "Nobody knows about carbon nanotubes at high rates of strain, because no one has checked."

Another application could be oil drilling. "Since carbon-nanotube fibers are not only strong, but also resist heat and corrosion, they could be used in drill bits or pipes to cope with these extreme environments," says Thomas.

Thomas cautions, however, that Windle and his colleagues got their best results for fibers about one millimeter long, apparently because the longer the strand, the more likely it is to contain small chunks of carbon and other defects that weaken it. "Tweaking the processing--the wind-up speed and the acetone treatment--isn't going to change the carboneous particles," Thomas says. "They've got to go back into the chemical synthesis" to address that.

"For the army to be interested in it, they'd want to have kilometers of it," he says. Nonetheless, the new results give him "lots of hope."

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