Researchers create new high-performance fiber

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Researchers at Northwestern University have nanoengineered a new kind of fiber that could be tougher than Kevlar.

Working in a multidisciplinary team that includes groups from other universities and the MER Corporation, Horacio Espinosa, James N. and Nancy J. Farley Professor in Manufacturing & Entrepreneurship at the McCormick School of Engineering and Applied Science, and his group have created a high performance fiber from carbon nanotubes and a polymer that is remarkably tough, strong, and resistant to failure. Using state-of-the-art in-situ electron microscopy testing methods, the group was able to test and examine the fibers at many different scales — from the nano scale up to the macro scale — which helped them understand just exactly how tiny interactions affect the material's performance. Their results were recently published in the journal ACS Nano.

"We want to create new-generation fibers that exhibit both superior strength and toughness," said Espinosa said. "A big issue in engineering fibers is that they are either strong or ductile — we want a fiber that is both. The fibers we fabricated show very high ductility and a very high toughness. They can absorb and dissipate large amounts of energy before failure. We also observed that the strength of the material stays very, very high, which has not been shown before. These fibers can be used for a wide variety of defense and aerospace applications."

The project is part of the Department of Defense's Multidisciplinary University Research Initiative (MURI) program, which supports research by teams of investigators that intersect more than one traditional science and engineering discipline. Espinosa and his collaborators received $7.5 million from the U.S. Army Research Office for the study of disruptive fibers, which could be used in bulletproof vests, parachutes, or composite materials used in vehicles, airplanes and satellites.

To create the new fiber, researchers began with carbon nanotubes —cylindrical-shaped carbon molecules, which individually have one of the highest strengths of any material in nature. When you bundle nanotubes together, however, they lose their strength — the tubes start to laterally slip between each other.

Working with the MER Corporation and using the corporation's CVD reactor, the team added a polymer to the nanotubes to bind them together, and then spun the resulting material into yarns. Then they tested the strength and failure rates of the material using in-situ SEM testing, which uses a powerful microscope to observe the deformation of materials under a scanning electron beam. This technology, which has only been available in the past few years, allows researchers to have extremely high resolution images of materials as they deform and fail and allows researchers to study materials on several different scales. They can examine individual bundles of nanotubes and the fiber as a whole.

"We learned on multiple scales how this material functions," said Tobin Filleter, a postdoctoral researcher in Espinosa's group. "We're going to need to understand how molecules function at these nanometer scales to engineer stronger and tougher fibers in the future."

The result is a material that is tougher than Kevlar — meaning it has a higher ability to absorb energy without breaking. But Kevlar is still stronger — meaning it has a higher resistance to failure. Next, researchers hope to continue to study how to engineer the interactions between carbon nanotube bundles and between the nanotubes within the bundle itself.

"Carbon nanotubes, the nanoscale building blocks of the developed yarns, are still 50 times stronger than the material we created," said Mohammad Naraghi, a postdoctoral researcher in Espinosa's group. "If we can better engineer the interactions between bundles, we can make the material stronger."

The group is currently looking at techniques — like covalently crosslinking tubes within bundles using high-energy electron radiation – to help better engineer those interactions.

Filleter and Naraghi said this work wouldn't have been possible without the interdisciplinary team that includes merging academia with industry.

"To work in an environment where we can trade information back and forth is a unique opportunity that will push the technology farther," Naraghi said. "MER has given us a unique raw material and a commercial perspective on the project. In turn, we provide the fundamental scientific understanding."

Provided by Northwestern University