The new superstrong

July 11 2013, by Angela Herring

Mechanical and industrial engineering assistant professor Marilyn Minus has developed a superstrong fiber that rivals the best in the industry. Credit: Mary Knox Merrill

In today's market for high performance fibers, used for applications such as bulletproof vests, manufacturers have only four options: Kevlar, Spectra, Dyneema, and Zylon. Made from polymers such as polyethylene, these were the strongest synthetic fibers in the world—until recently.

Marilyn Minus, an assistant professor of engineering at Northeastern, has developed a type of fiber that is stronger than the first three commercial products mentioned above, and—even in its first generation—closely approaches the strength of the fourth (Zylon).

Adding small amounts of carbon nanotubes—straight, cylindrical particles made entirely of carbon—to polymer fibers increases their strength marginally. But as a graduate student at the Georgia Institute of Technology five years ago, Minus figured that with a little more control, she might be able to turn those modest improvements into dramatic ones. She has spent the last four years at Northeastern proving her hunch.

In a paper recently released in the journal *Macromolecular Materials and Engineering*, Minus presented a tunable process for creating super-strong fibers that rival the industry's very best. As with previous work, Minus' method integrates carbon nanotubes into the polymer fiber, but rather than serving as simply an added ingredient, the nanotubes now also perform an organizational role.

From carbon black powder to metallic particles, a variety of materials can guide the formation of specific crystal types in a process called nucleation. But before carbon nanotubes, Minus said, "we've never had a nucleating material so similar to polymers."
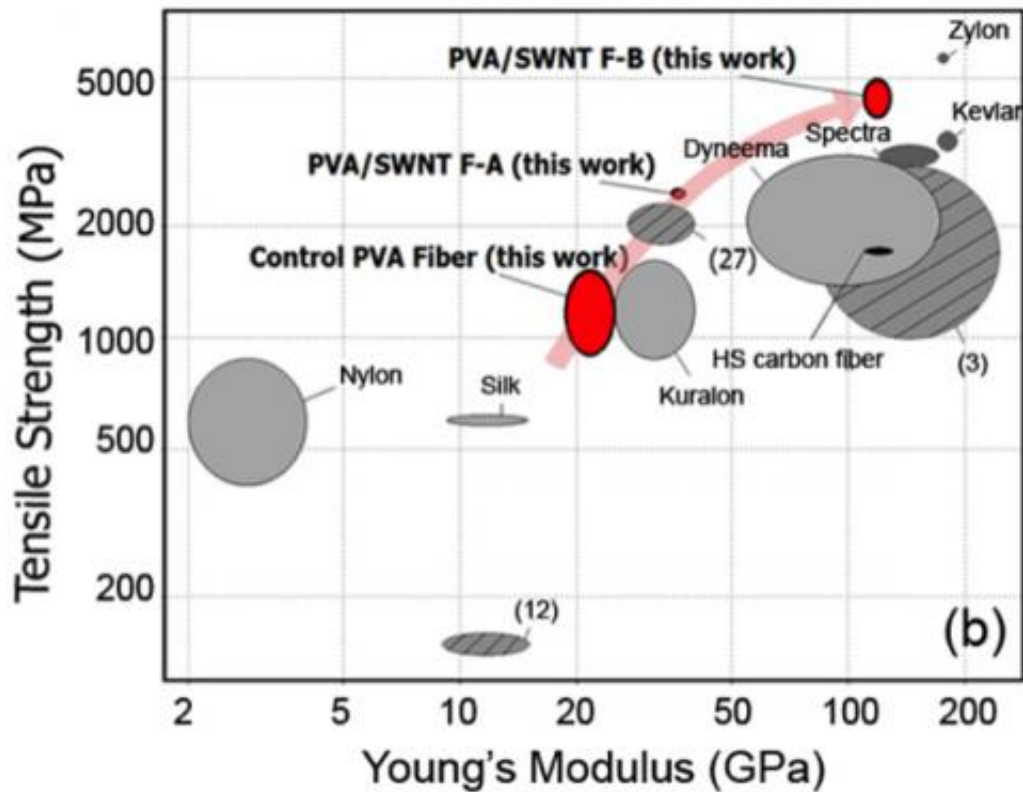
The fibers created by Minus' team are shown in red. Tuning the crystallization process makes them stronger than any other material on the market except for Zylon. Credit: Marilyn Minus.

This similarity allows the nanotubes to act likes skates along which the long polymer chains can slide, perfectly aligning themselves with one another.

But it's the crystallization process that drives the remarkable properties recently reported. In their research, Minus and her colleagues showed that they could easily turn these properties on or off. By changing nothing but the pattern of heating and cooling the material, they were able to increase the strength and toughness of fibers made with the very same ingredients.
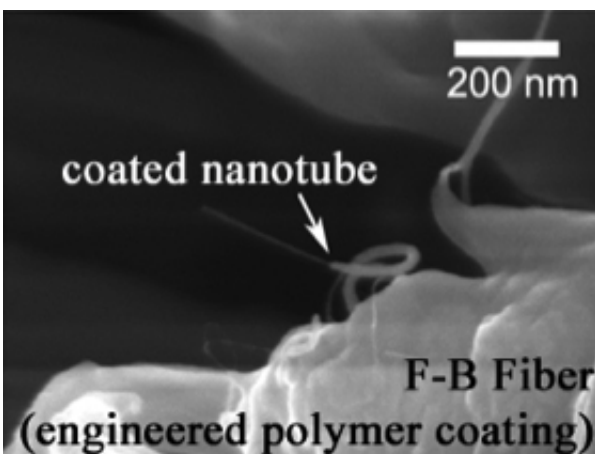
After using tuning the crystallization process, electron microscope imaging shows that the nanotubes inside the fiber are coated in polymer. Credit: Marilyn Minus

In the current research, Minus and her colleagues worked out the recipe and process for one particular polymer: polyvinyl alcohol. "But we can do this with other polymers and we are doing it," she said.
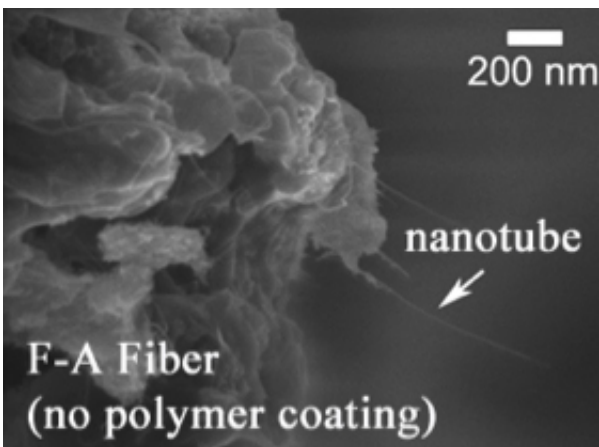
Simply combining the nanotubes and polymer does not induce the polymer to uniformly coat the nanotube. Credit: Marilyn Minus

With funding from a new grant from the Defense Advanced Research Projects Agency, Minus will now work out the method for a polymer called polyacrylonitrle, or PAN. This is the dominant material used to form carbon fibers, which are of particular interest in lightweight composite materials such as those used in the Boeing 787 airliner. With the more organized structure afforded by Minus' method, this material could see a vast increase in its already great performance.

More information: [onlinelibrary.wiley.com/doi/10 …](onlinelibrary.wiley.com/doi/10) e.201300025/abstract

Provided by Northeastern University