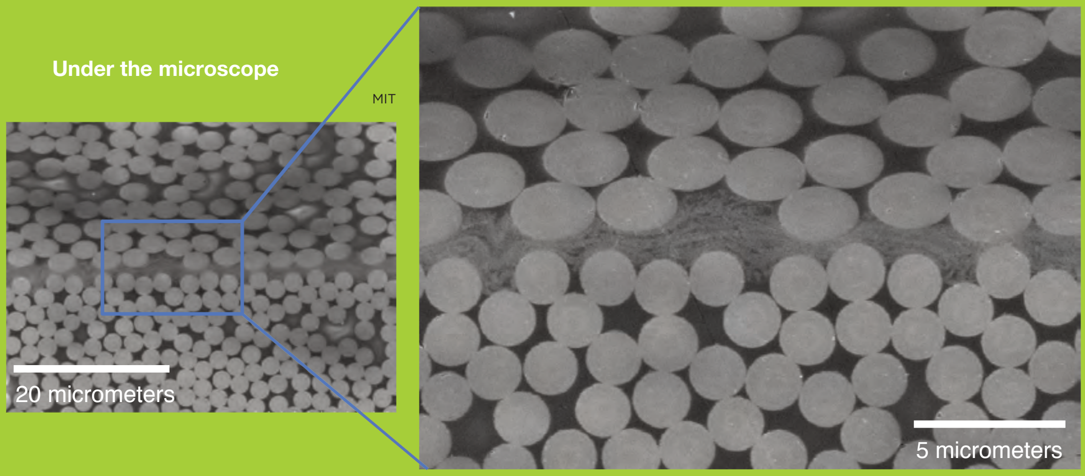
Under the microscope



Reinforcement: Adding aligned carbon nanotubes (the light gray material in the center of this scanning electron micrograph) to a polymer strengthens the bond between laminates of composite fibers, shown here in a cross section.

Nanotubes for stronger composites

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Aerospace engineers at the Massachusetts Institute of Technology have shown that carbon nanotubes can act like nanoscopic stitches to bind layers of composite materials and prevent delamination.

The goal of the research is to address an Achilles heel of today's aerospace composites.

"Nothing holds the composite layers together except polymer glue and there is no good technological fix," explains Brian Wardle, an entrepreneur and an aeronautics and astronautics professor at MIT and director of its Nano-Engineered Composite aerospace Structures Consortium, a research group focused on creating new materials.

Conventional methods of stitching or weaving together layers of composite material can damage the fibers and reduce their ability to withstand impact. To find a better way, Wardle worked with MIT postdoctorate researcher Roberto de Guzman de Villoria and engineers from Sweden's Saab AB to embed more than 10 billion carbon nanotubes in vertical alignment in each square centimeter of a glue-like polymer between composite layers. The carbon nanotubes, which are 1,000 times smaller than the composite fibers, poked into microscopic regions between carbon fibers in adjacent composite layers and acted like stitches to bind the layers.

To test the concept, the team grew a forest of carbon nanotubes and embedded them in a polymer contained in 16-layers of a composite laminate. When the researchers heated the flexible composite laminate, the polymer flowed from the pre-impregnated plies into the carbon nanotube forest. The researchers tested the material's strength under a variety of conditions.

In one test, researchers drove a bolt through the composite material and ripped out the bolt to intentionally damage the fibers. Even with the damage, the material withstood 30 percent more force before breaking than composites without nanotube stitches. In another test, researchers forced the bolt hole closed, and the material withstood 14 percent more force than conventional composites. The results were to be published in the Sept. 14 issue of the journal Composites Science and Technology.

"We were surprised by how much the nanoscale stitches improved the strength of the composites," Wardle says. "In more recent tests, the improvement is even larger" than those to be reported in the journal article.

Because these research results were achieved during static tests conducted in ambient conditions, MIT researchers are continuing to evaluate how well the polymer withstands the fluctuating forces known as cyclic stress as well as their durability in the face of environmental extremes, including hot and wet conditions.

Industrial challenges also lie ahead.

"Companies around the world are getting better at making large quantities of these sorts of materials," says Wardle, who founded N12 Technologies Inc. of Cambridge, Massachusetts, to address the problem. "But more work is needed."

When these materials can be produced in bulk, they will help make airplanes lighter and stronger, says Guzman de Villoria, the postdoctoral researcher who now works at the Madrid Institute for Advanced Studies of Materials. Composites make up more than 50 percent of the weight of new planes. If the bond between composite layers is stronger, aircraft designers will be able to rely even more heavily on composites, which could lead to lighter weight aircraft that use less fuel and emit less pollution, Guzman de Villoria says.

Initially, the nanotube stitches may fly in unmanned aircraft.

"In much the same way composites made their way into aircraft, carbon nanoscale stitches will make their way into commercial and military aircraft in secondary and tertiary structures, such as cargo bay doors, hatches and flaps," Wardle says. ★