Scientists use carbon nanotube networks to detect defects in composites

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Two University of Delaware researchers have discovered a means to detect and identify damage within advanced composite materials by using a network of tiny carbon nanotubes, which act in much the same manner as human nerves.

The discovery has important implications both in the laboratory, where the scientists hope to better predict the life span of various composite materials, and in everyday applications, where it could become an important tool in monitoring the health of composite materials used in the construction of a variety of essential products, including commercial airliners.

The research is the work of Tsu-Wei Chou, Pierre S. du Pont Chair of Engineering, and Erik Thostenson, assistant professor of mechanical engineering, and will be featured in an article in the Oct. 2 issue of the influential journal *Advanced Materials*.

Chou said the research team has been working in the field of fiber composites in conjunction with UD's Center for Composite Materials and of late has taken an interest in the reinforcement of composites with minute nanomaterials--a nanometer is a bare one billionth of one meter--and particularly with carbon nanotubes.

"Carbon nanotubes are very small but have superb qualities," Chou said. "They are very light, with a density about one-half that of aluminum, which itself is considered exceptionally light in comparison to other metals, and yet are 30 times as strong as high-strength steel and as stiff as diamonds."

Besides being very strong and very light, the carbon nanotubes have an incredible ability to conduct heat and electricity. In the latter case, they are 1,000 times more effective at carrying an electrical current when compared to copper.

"Carbon nanotubes have excellent properties and the challenge has been how best to utilize them, to translate those properties into applications," Chou said.

Given the various properties, Chou and Thostenson set out to develop the carbon nanotubes as sensors embedded within composite materials.

Composite materials are generally laminates, sheets of high-performance fibers, such as carbon, glass or Kevlar, embedded in a polymer resin matrix. Chou said that the traditional composite materials have inherent weaknesses because the matrix materials--plastics--surrounding the fibers are "strong, but far less strong than the fibers."

This results in "weak spots in composites in the interface areas in the matrix materials, particularly where there are pockets of resin," Chou said.

As a result, defects, including tiny microcracks, can occur. Over time, those microcracks can threaten the integrity of the composite.

Thostenson said the carbon nanotubes can be used to detect defects at onset by embedding them uniformly throughout the composite material as a network capable of monitoring the health of the composite structures.

"Nanotubes are so small they can penetrate the areas in between the bundles of fiber and also between the layers of the composite, in the matrix rich areas," Thostenson said.

Because the carbon nanotubes conduct electricity, they create a nanoscale network of sensors that work "much like the nerves in a human body," he said.

The researchers can pass an electrical current through the network and "if there is a microcrack, it breaks the pathway of the sensors and we can measure the response," Thostenson said.

He added that the carbon nanotubes are minimally invasive and just 0.15 percent of the total composite volume.

At present, composite material engineers have limited means to either detect the initial onset of microcracks or identify the specific type of defect. This finding will change that because the method is simple, does not require expensive equipment and is remarkably sensitive to the initial stages of microcracking, Thostenson said.

For the technique to be successful the carbon nanotubes must be scattered everywhere throughout the material and Chou credited his colleague with "developing a technique for disbursing the carbon nanotubes very uniformly in the matrix material."

The work provides a new tool for research in the laboratory at present and has many potential applications in the future. By identifying and tracking defects in a laboratory setting, the researchers can now begin to develop strategies for more accurate predictions of the lifespan of composite materials.

"This is a very practical 'today' project," Thostenson said. "We can take advantage of this new scale now with wide applications in the future."

That is very important given the growing applications of composite materials in everyday life. Composites are used in sporting goods, civil infrastructure including bridges and pipes, and transportation, particularly in the aircraft industry.

Chou noted that the new Boeing 787 Dreamliner is 50 percent composites by weight and more than 50 percent by volume, making "the successful monitoring of composite structures very important."

"These are significant issues, being able to detect defects and to understand what is the life cycle of a given composite," Thostenson said. "It comes down to, how long will the composite last, at what point will the structure no longer be viable?"

Source: University of Delaware

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