

Manufacture and Characterization of a Layered Carbon Fiber Material Covered with Carbon Nanotubes

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Introduction

In the past decade and a half there has been extensive research about carbon nanotubes (CNTs) and their possible applications because of the unique characteristics they possess. CNTs can act as metals or semiconductors (depending on the chirality), have extraordinary strength and elasticity (on the order of tens of GPa and 1 TPa, respectively), have a resistivity of $10^{-4} \Omega \cdot \text{cm}$, and thermal conductivity of about $2000 \text{ W/m}\cdot\text{K}$. They have applications in many different fields from materials science to biomedical science. There are, although, difficulties with CNTs that has hindered the transition between application and mass production. First, there is no known way to produce only the semiconductor or metal characteristic CNTs; they are produced in mixtures of the two. Secondly, CNTs are very expensive to produce and there has yet to be a cost effective way to mass produce them in their applications.

One application of CNTs is using them as reinforcement in other materials. This is done mainly by growing them separately and mixing them with or bonding them to the substrate material. However, CNTs can also be grown directly on certain substrate materials. One of these materials is carbon fiber (CF). CF is very lightweight, strong, electrically and thermally conductive, and can withstand the 800°C temperatures used when growing the CNTs. The objective of this research is to 1) learn how to effectively grow CNTs on CF, 2) quantify the effects, and 3) find a way to cost effectively produce large amounts of this material.

Procedure

Different types of woven CF were cut into 2" square pieces. A piece of CF was first deposited with an iron catalyst about 4 nm thick on both sides using a thermal evaporator (TE). Then the CF was placed in a chemical vapor deposition (CVD) where it was heated to 820°C while various hydrocarbon gases flowed over the sample, thus growing the CNTs. Once a type of fiber was found to work well the sample size was increased.

Results and Discussion

Based on the SEM photos the CNT growth was $20 \mu\text{m}$ thick and uniform. The good growth was due to the fact that there was complete deposition of the catalyst and the weave of the CF had small holes where the hydrocarbon gases could penetrate it in the CVD and evenly grow the CNTs. Figure 1 shows woven CF where a mask was used to show CNT growth on only a part of it.

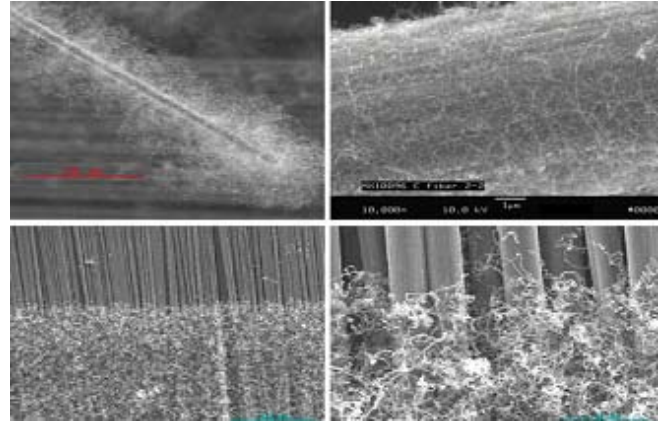


Figure 1: SEM photos of (top row) a single strand of CF with CNTs and (bottom row) woven CF partially covered with CNTs

The CF sheets that were covered with CNTs on both sides were then layered together 5 thick using an epoxy resin. The sheets were then tested using a delamination strength test where the force to pull apart two plies of the material was measured. The results from this test are shown in Figure 2. The CNTs increased the delamination strength by 44%. This increase is due to the strong CNTs acting as a microscopic Velcro between the plies. Future work on the project involves growing on larger pieces of the CF and putting the material through a variety of ASTM tests. Thermal and electrical conductivity can also be tested.

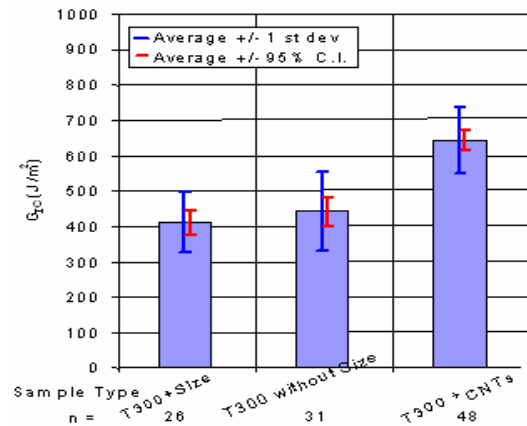


Figure 2: Delamination Strength Summary

Conclusion

The CNTs were very effectively grown on the CF and a great increase in strength was found in the CF material. A more efficient method to grow the CNTs on the CF all at once was also devised. The CF piece sizes have ranged from 2" squares to 4" x 12".