SYNTHESIS AND PROPERTIES OF CNT COMPOSITES

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Introduction

Carbon nanotubes (CNTs) are half Bucky sphere-capped hollow graphene cylinders, which have exceptional properties including breaking strengths of ~30 GPa at a density of about 1.2 g/cc to 1.4 g/cc and a linear elastic modulus of almost 1 TPa. The thermal conductivity can be many times that of copper and individual CNT tubes can carry 1000 more current than copper[1]. The first documented deliberate production of carbon nanotubes was in 1952 by Radushkevich and Lukyanovich[2], followed by work of Bacon[3] on graphite single crystals, and Endo[4] who pioneered the use of the floating catalyst method and was highly instrumental in scaling this technology for mass production. Structural characterization of single wall CNTs by Ijima[5] stimulated wide attention to the unique single wall form of CNTs. TEM studies by Baker[6] and Bethune[7] helped the understanding of their distinct cylindrical morphology. The challenge for Nanocomp is to fabricate CNT articles in the form of sheets or yarns that can take advantage of the extraordinary properties of these very small building blocks. This paper will describe our approach.

Nanocomp uses a modified floating catalyst method[8] for continuous synthesis of over 3 grams per hour of CNTs that can be caused to deposit on cylinder or belt to form a phyllo dough type of sheet or on a moving anchor from which a yarn can be directly spun.

These sheets, Figure 1a, can be up to 8 feet long and seamed to produce rolls and can be 'prepregged' on commercial resin pre-impregnation systems, Figure 1b.

Figure 1 (a) A 25 foot long CNT sheet and (b) a commercial prepregger infiltrating a 200 foot long DWCNT roll.

Experimental

How sheets are formed
Large CNT sheets are formed by causing the cloud of CNT's to deposit on a moving cylinder or belt. The material builds up like a 'phyllo-dough' as the belt slowly translates back and forth. The nature of the CNTs can be tailored though the process parameters from single walls (SWCNT), dual walls (DWCNT) or multiwalls (MWCNT).

Composites Fabrication
Small additions of dispersed carbon nanotube to an resin (epoxy) can increase viscosity by 4 orders of magnitude.[9] So that CNT polymer composites are usually limited to concentrations of less than 2 wt%, which limits mechanical property enhancements. The addition of resins to CNT preformed sheets; however, takes advantage of capillary forces to help draw the resin throughout the sheets even with low porosity so that CNT loadings of 40 to 50% are for the first time possible on commercial prepreg machines.

An example of a cross section of a CNT sheet over laid on a graphite epoxy panel is shown in Figure 2. These show that for this toughened epoxy resin, full penetration was achieved.

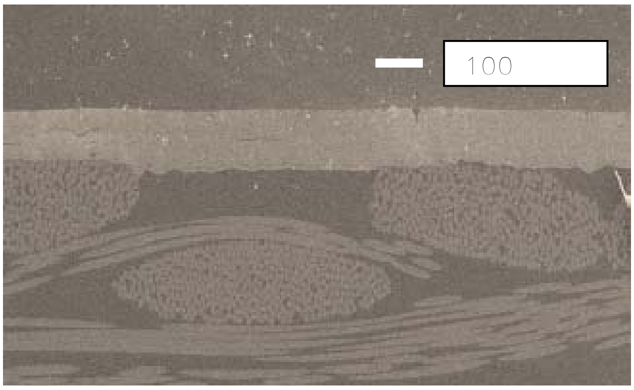

Figure 2. A prepregged CNT sheet bonded during fabrication to ordinary graphite composite. This geometry imparts extraordinary electric properties to the composite.

Advantages of CNT Composites

An advantage of CNT materials compared with graphite based materials is that the resultant material is very ductile. For example graphite PEEK composite fiber tape with a thickness of about 0. 2" cannot be bent around a even a gradual radius without cracking whereas a CNT based PPS composite tape of the same thickness will not crack even if bent around a radius of 0.063" An example of such a fracture is shown in Figure 3 and an SEM of the surface in Figure 4.

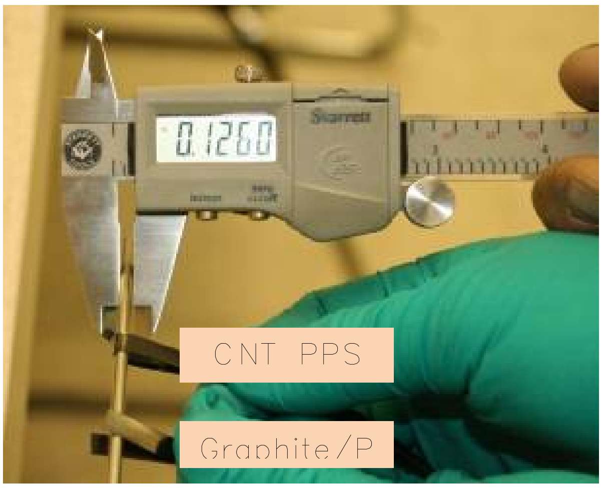

Figure 3 An example of Graphite PEEK based tape 'failing' around a small bend radius compared with a CNT PPS based tape. Both tapes have about the same chord modulus, thickness, and breaking strength.

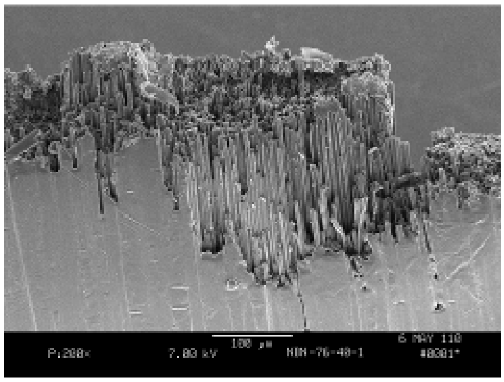

Figure 4. An SEM micrograph at 7 keV of graphite Peek composite fractured as in Figure 3.

Conclusions

Carbon nanotube based composites can now be produced with very high loadings of CNT with almost any resin. They exhibit far more ductility that comparable graphite based composites. Materials are now available as prepregs with toughened epoxy, PPS, BMI, PU and cyanate ester type resins.

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