CONDUCTIVITY OF SINGLE WALL NANOTUBE (SWNT) / POLYACRYLONITRILE (PAN) / DIMETHYL FORMAMIDE SOLUTION (DMF) FOR GELATION INTO PAN/SWNT COMPOSITE FILMS

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Introduction

On of the most prominent areas of research in nanotechnology involves the iconic nanotube, a tubular structure of pure carbon that comes in multi-wall, double-wall, or single wall form, with each variation possessing different properties. Carbon nanotubes are most widely recognized for possessing the highest strength of any known material, but their other properties have been gaining recognition, including their electrical properties, particularly when in composite with other materials. About 90% of the carbon consumption in the world goes to Polyacrylonitrile (PAN)-based carbon-composite fibers due to the high tensile strength and low volume fraction of voids of the composite. In addition, PAN/ Single Wall Nanotube (SWNT) composites have been researched for possible use as supercapacitors.

A dominant factor affecting the properties of PAN/SWNT composites is the dispersion of SWNT in the initial mixture. Previous testing has alluded that in a solution containing SWNT, the conductivity of the solution is related to the degree of dispersion of the SWNT in the solution. Therefore, it may be possible to determine the degree of dispersion in a solution by measuring the solution's conductivity. Another factor affecting the properties of the final composite is the method used to process the solution. Prior work on PAN/SWNT composites has been primarily concerned with gel spinning with little work done with the comparative technique of gel drawing. The comparative resulting SWNT orientation in the final material is uncertain at present.

Procedure

A 1-wt % SWNT / DMF mixture was sonicated for six hours. 2-wt % 900K MW PAN was then added to the dispersion, which was then vacuum-purged of water. The SWNT/PAN/DMF solution was mixed at 800 rpm on a hot plate at 60 °C for three weeks, with the conductivity of the solution being measured daily. On days 4, 7, and 21 of mixing, solution was removed and used to form films.

To measure conductivity, the motor was turned off and the multimeter probe was submerged in solution. The multimeter was programmed to measure voltage while applying a stair-step sweep of currents from 0.01 µA to 1.0 µA in 0.11 µA steps with 0.001, 1.0, 10, 30, 60, and 120 seconds per stair-step, starting with 120 sec and descending. Between sweeps, the probe was cleaned with DMF and air-dried.

The SWNT/PAN films were formed by gelation. In this process, a level stand was placed in a Styrofoam cooler. The glass mold was placed on the stand. The remainder of the container was filled with ice up to just below the top of the stand, evenly distributing the ice around and beneath the stand. The solution was then poured into the cold mold, forming an even layer. The cooler was closed and the mold was chilled for 24 hours. The formed gel was removed from the mold and placed in methanol to remove excess DMF and for storage.

Results and Discussion

The plotting of the conductivities of the different step-times defied quantifying. The spread for any given step-time was too diffuse to derive any specific pattern. The plots were expected to start with a low conductivity, stay level, then increase, and finally level off at a higher conductivity. Instead, the conductivities as shown in Fig. 1 started at high values and stayed high.

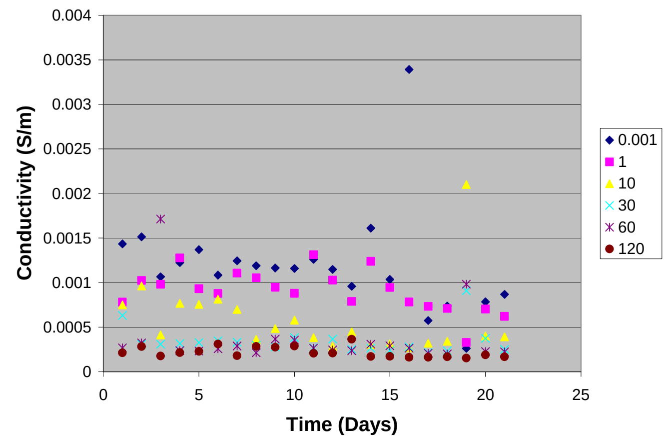

Fig. 1: SWNT/PAN/DMF solution conductivity vs. day of testing for step-times.

Qualitatively, it was determined that, as stair-step time decreased, the solution conductivity increased though no discernable trend developed with the passing of time (days).

The measuring of the dispersion of SWNT in a solution by the measuring of the solution's conductivity was a unique method. Because such a low concentration (1 wt %) of SWNT was used, the dispersion was good from the start, therefore not much improvement was able to occur. This good dispersion resulted in the high overall conductivity.

Conclusion

This study demonstrated that as the time over which a current was applied to a PAN/SWNT/DMF solution decreased, the conductivity increased. However, the concentration of the SWNT in solution was sufficiently low as to make equilibrated dispersion from the beginning of testing. This test therefore did not conclusively show measuring conductivity to be a viable technique for measuring dispersion. A revision of this experiment involving a higher SWNT concentration might produce a clearer trend.

References

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