HIGH THERMAL CONDUCTIVITY CARBON/CARBON COMPOSITES MADE FROM PBO-BASED CARBON FIBERS

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Introduction

High-performance composites are exceptionally light and exhibit mechanical properties that are superior to conventional metals. Currently, fiber-resin composites dominate the industrial market. However, carbon fiber reinforced carbon composites can also be used in many industrial applications. Carbon in its various forms is one of the most versatile thermal management materials because its thermal conduction properties can be tailored to meet the needs of a given application. Recent emphasis has been placed on developing carbon-carbon composites for thermal management. Using high thermal conductivity fibers in a carbon matrix results in a high strength, low density composite with good thermal properties.

Poly(p-phenylene benzobisoxazole), PBO, appears particularly promising as a fiber precursor. The fiber has a large proportion of aromatic carbons which results in a high carbon yield. Because of its high degree of orientation and exceptional crystallinity after carbonization, PBO yields an anisotropic carbon fiber with low electrical resistivities and strengths comparable to commercial carbon fibers.

Experimental

The PBO fiber, provided by TOYOBO Company, was coated with a phenol formaldehyde resin, Varcum 29327, using a powder coating technique, developed at Clemson University, and using a solution coating technique. The coated fibers, or towpreg, were then wrapped, using a fiber mandrel to make a unidirectional (1D) composite. The amount of resin used, in the powder coating technique, was varied for each sample set in order to assist in determining the density and porosity variations incurred from the carbonization of the composite. The amount of powder used in the solution coating was based upon results of the powder coating.

The PBO fiber/phenolic resin composites, or green composites, were consolidated at a temperature of 177 °C and at a pressure of 340 atm. for 15 minutes. After consolidation the green composites were cured at 100 °C for 12 hours. The resulting cured composites were then carbonized to 1100°C. The heating ramp used was 7 °C per minute from 25 °C to 160 °C, 1 °C per minute from 160 °C to 500°C, 3 °C per minute from 500°C to 900°C, and 10 °C per minute from 900 °C to 1100°C. Selected samples were further heat treated to a temperature of 2400 °C. The heating ramp used was 20 °C per minute to 1800 °C and 10 °C per minute to 2400 °C.

All heat treated composites were viewed under an optical microscope at a magnification of 40X to observe the fiber-matrix interface and calculate the volumetric void fraction. The volumetric void fraction was computed using video image analysis. The flexural modulus was determined using the ASTM D-790 four-point flexure test procedure, and the electrical resistivity was determined using the ASTM C-611-84 test procedure. The physical properties of the composites produced from each coating technique were compared statistically to demonstrate that changing techniques did not adversely affect the composites.

Results and Discussion

Optical observation of the carbonized samples showed a good fiber-matrix interface. Few cracks or voids were noticed at the interface. This is believed to be the result of the unique properties of the fiber and its interactions with the phenolic resin. Cracks and voids, ranging in size, were observed in the matrix. The cracks are caused by the release of accumulated stresses incurred during carbonization. The smaller voids are the result of the evolved gases being contained in the carbonizing composite.

The flexural modulus of the composites are shown in Figure 1. The data indicate that the solution coated composites have similar flexural moduli to the powder coated composites, at corresponding volumetric fiber fractions.

The calculated electrical resistivities are shown in Figure 2. The electrical resistivities, along the fiber axis, of the samples are greater than previous work performed at Clemson University(1). The higher resistivities are caused by the stress cracks that are oriented perpendicular to the fiber axis, thus inhibiting the pathway of the current. Graphitization, of randomly selected samples, reduced the electrical resistivities to half their original value.

Conclusions

The relatively low electrical resistivities demonstrate the C/C composites potential as an adequately conductive material. However, the cracks oriented transverse to the fiber axis need to be addressed to avoid potential problems in thermal applications. The process to coat the fiber, powder or solution, causes no statistically significant change in physical properties.

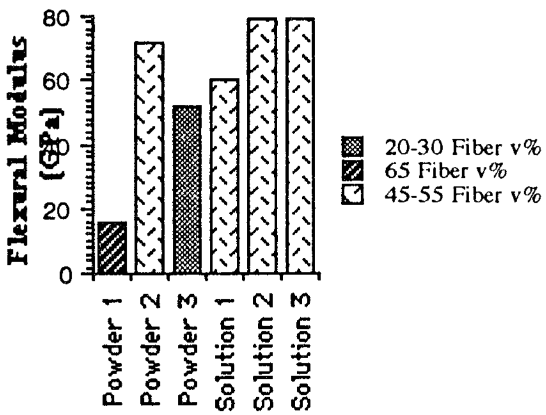

Figure 1: Flexural Modulus of Powder Coated Composites and Solution Coated Composites

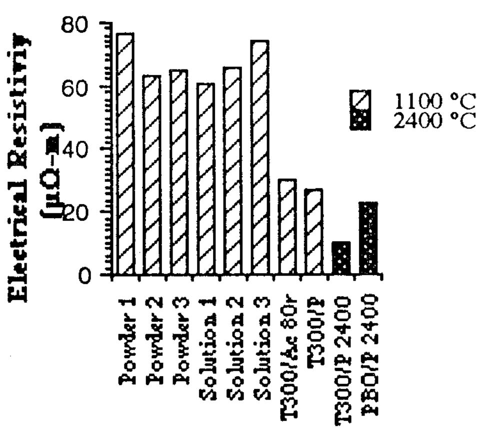

Figure 2: Electrical Resistivities for Various Carbon/Carbon Composites with Different Heat Treatments

References

1. Dayrit, R. M., Masters Thesis, Clemson University, Clemson, South Carolina, (1996).