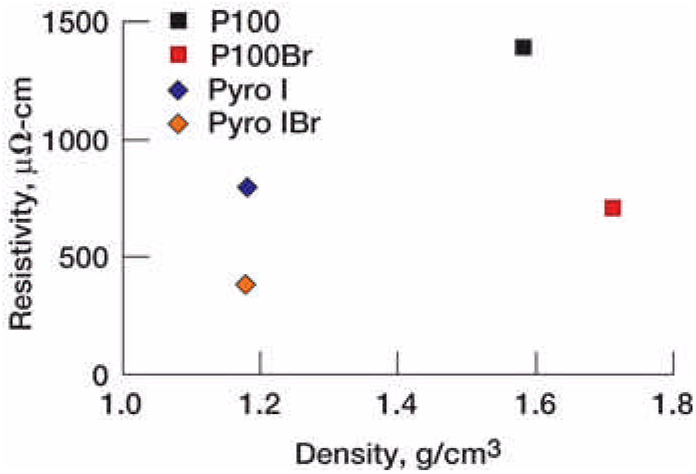
Resistivity of Carbon-Carbon Composites Halved

Carbon-carbon composites have become the material of choice for applications requiring strength and stiffness at very high temperatures (above 2000 °C). These composites comprise carbon or graphite fibers embedded in a carbonized or graphitized matrix. In some applications, such as shielding sensitive electronics in very high temperature environments, the performance of these materials would be improved by lowering their electrical resistivity.

One method to lower the resistivity of the composites is to lower the resistivity of the graphite fibers, and a proven method to accomplish that is intercalation. Intercalation is the insertion of guest atoms or molecules into a host lattice. In this study (ref. 1) the host fibers were highly graphitic pitch-based graphite fibers, or vapor-grown carbon fibers (VGCF), and the intercalate was bromine. Intercalation compounds of graphite are generally thought of as being only metastable, but it has been shown that the residual bromine graphite fiber intercalation compound is remarkably stable, resisting decomposition even at temperatures at least as high as 1000 °C (ref. 2). The focus of this work was to fabricate composite preforms, determine whether the fibers they were made from were still intercalated with bromine after processing, and determine the effect on composite resistivity. It was not expected that the resistivity would be lowered as dramatically as with graphite polymer composites because the matrix itself would be much more conductive, but it was hoped that the gains would be substantial enough to warrant its use in high-performance applications.

In a collaborative effort supporting a Space Act Agreement between the NASA Glenn Research Center and Applied Sciences, Inc. (Cedarville, OH), laminar preforms were fabricated with pristine and bromine-intercalated pitch-based fibers (P100 and P100-Br) and VGCF (Pyro I and Pyro I-Br). The green preforms were carbonized at 1000 °C and then heat treated to 3000 °C. To determine whether the fibers in the samples were still intercalated after composite fabrication, they were subjected to x-ray diffraction. The composites containing intercalated graphite fibers showed much higher background scatter than that of pristine fibers, indicating the presence of bromine in the samples. More importantly, faint features indicative of intercalation were visible in the diffraction pattern, showing that the fibers were still intercalated.



Resistivity of carbon-carbon composites made from pitch-based fibers (P100), bromine-intercalated pitch-based fibers (P100-Br), vapor-grown carbon fibers (Pyro I), and bromine-intercalated vapor-grown carbon fibers (Pyro I-Br).
This figure shows a resistivity as a function of density plot containing four data points. It shows that there is a factor of 2 lowering of the resistivity for both pitch-based and vapor-grown graphite fiber composites.

The resistivity as a function of density of the composites is shown in the graph. As expected, the resistivity of the VGCF composites was lower than that of the pitch-based fiber composites. The resistivity of the bromine-intercalated fiber composites of both types was lower than their pristine counterparts by a factor of 2. This is compelling evidence that the fibers remained intercalated, though the composite resistivity was not lowered by as large a factor as the fiber resistivity was lowered. However, the resistivities of the composites were comparable to that of polymer composites (ref. 3) in spite of the fact that the matrix was not fully graphitized, and so fiber-to-fiber contacts were less than ideal. Thus, a new route to making highly conductive, high-temperature, low-weight materials has been demonstrated.

References

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