A Comparison of Electrical Properties of Unintercalated, and Intercalated Vapor-Grown and Pitch-Based Carbon Fibers

by

John A. Woollam, Rodney O. Dillon, and Duane E. Meyer
Department of Electrical Engineering
University of Nebraska, Lincoln, NE 68588-0511

and

Suraiya Nafis and David J. Sellmyer
Department of Physics
University of Nebraska, Lincoln, NE 68588-0111

and

James Ho**
Wichita State University, Wichita, KS 67202

Introduction

Methane derived vapor grown fibers have attracted considerable interest recently as hosts for high conductivity intercalated graphite conductors.[1,2] After anneal they are highly graphitic and exhibit exceptionally low electrical resistivity. Pitch based fibers on the other hand, do not have as low electrical resistance, but are mass producible in long lengths at relatively low cost.

We have been growing carbon fibers at UNL by vapor transport in a methane-hydrogen mixture at 1100°C. Fibers of several inches in length, and up to 100 microns diameter have been grown. These fibers have been annealed at a series of temperatures from 1500°C to 3000°C and their properties studied.

In addition, we have studied a series of Union Carbide P100 pitch based carbon fibers annealed to temperatures above 3000°C. All fibers have been characterized electrically both before and after intercalation.

Characterization

An important question regarding our vapor grown fibers is how do they compare structurally and electrically to fibers grown by Endo[1], by Tibbets[2], and by Chin[3], et al. Our structurual studies are principally done using scanning electron microscopy. Electrical measurements include resistivity and magnetoresistivity, both as a function of temperature. Results of our measurements, and comparisons with results on similar materials will be presented.

Annealing and Intercalation

UNL vapor grown fibers annealed between 1500°C and 3000°C. Both vapor grown and pitch based fibers are intercalated with:

H_2SO_4 - electrochemically,

$EuCl_3$ - from the vapor,

Bromine - from the vapor

The $EuCl_3$ intercalant is of interest because the optical Drude edge[3] in intercalated HOPG is coincident with that for $SbCl_5$ intercalated HOPG. The latter forms compounds of low electrical resistance[5] with HOPG. They are also of interest because Eu is a magnetic ion. Electrochemical intercalations are of interest because the staging transitions can be easily followed in situ, and this method affords good control. A reference potential is used to monitor the intercalation. Intercalation of P100-4 fibers with H_2SO_4 results in a reduction in resistivity by a factor of ten. For comparison, the time dependence of electrochemical intercalation of H_2SO_4 into HOPG results in a gradual reduction in ac electrical resistance up to a factor of four. A large increase in ac resistance is found concurrently with a large step in the reference potential near reaching stage 1.

Conclusions

Carbon fibers have been grown from the vapor and annealed to 3000°C. Comparisons of electrical properties are made with fibers grown in other laboratories from the vapor phase. Intercalations of both vapor grown, and pitch based fibers by $EuCl_3$, bromine, and H_2SO_4 are made and comparisons of electrical properties made.

References

1. M. Endo, and H. Veno, "Growth and Applications of Vapor-Grown Carbon Fibers", Extended Abstracts, Materials Research Society, Symposium on Graphite Intercalation Compounds, November 1984, p. 177.

2. G. G. Tibbets, "From Catalysis to Chemical Vapor Deposition: Graphite Fibers from Natural Gas", Extended Abstracts, Materials Research Society, Symposium on Graphite Intercalation Compounds, November 1984, p. 196.

3. L. D. Woolf, J. Chiu, Y. R. Liu-Liu, and H. I. Kezi, Phys. Rev. B30, 861 (1984).

*Research supported by NASA Lewis Grant NAG-3-95
**Supported by Wright Patterson Air Force Base, Dayton, OH.