

# POSTER

## EFFECT OF STABILIZATION ON PROPERTIES AND MICROSTRUCTURE OF CARBON FILMS

Tse-Hao Ko and C. H. Chen

Department of Materials Science  
College of Science  
Feng Chia University  
Taichung, Taiwan  
Republic of China

### Introduction

Carbon films can be expected to have interesting physical properties such as high conductivity, optical anisotropy, and high radiation resistance, and, therefore, can be applied as a new material in the fields of advanced technology. Our previous study presented the variation of physical properties of PAN fibers during the stabilization process[1-5]. In the present study, the effect of stabilization time on the physical properties and microstructure of the final carbon film is studied.

### Experimental

PAN films were solvent cast from dimethyl-formamide (DMF) solutions, with a concentration of 2.5g/40ml. PAN was 150000 Mw, obtained from Courtaulds Ltd. (U.K.). Films were spun on 18 cm by 20 cm quartz plates. The film thickness was controlled to near  $35\mu\text{m}$ .

The stabilization of the two PAN films was carried out in a constant temperature zone furnace with a purified air atmosphere, at 220 C for 2 hr and 6 hr, respectively. The resulting stabilized films were named films A and B, respectively. Sets of six different samples of both A and B were prepared by carbonizing the stabilized film in a ceramic reaction tube and a oxygen-free nitrogen atmosphere from 25 C to 300 C, 500 C, 700 C, 900 C, 1100 C and 1300 C, respectively.

### Results and Discussion

Figure 1 shows the variation in densities of stabilized film during the carbonization stage. Density increases very rapidly up to 1100 C for both films. This finding indicates that the crosslinking of ladder polymers as well as the lengthening and broadening of carbon basal planes

led to the repacking of the structure in carbon films. But the density increase was followed by a sharp drop above 1100 C. The reason for the drop in apparent density could be the conversion of open pores to closed pores. Recently, We found that fibers had a lower cumulative pore area in the temperature ranges above 1100 C. This was due to the close packing of the basal planes and the rearrangement of the structures around the pores.

The diffraction pattern of both samples was very similar during carbonization, regardless of temperature range. Figure 2 shows a typical comparison, for samples prepared at 1300 C.

These patterns show a very broad peak at  $2\theta=22.6$  degree, corresponding to the (002) planes. Such structures consist of a network of intertwined ribbons of stacked graphitic sheets. This structure is similar to those for so-called glass-like carbon.

The electrical resistivities of PAN-based carbon films were measured as a function of carbonization temperature, as shown in Figure 3. The resistivity decreases with increases in the formation of carbon layers in carbon films. In carbon layers, the conjugated  $\pi$ -bonding of the layered structure results in the electrons being delocalised throughout the structure providing a means of conducting electricity similar to metallic conduction bands[7]. The resistivity of film B was lower than that of film A during the carbonization process. Likewise, the Lc of film B was greater than that of film A. We assumed the superior properties of film B were due to the sufficient stabilization creating cyclization reactions, which led to enhanced order, which in turn promoted condensation of individual chains onto carbon-like structures during carbonization.

## Conclusions

A longer stabilization time promoted an increased number of ladder polymer structures in the stabilized film. The carbon films developed using a longer stabilization time have a greater density, greater carbon layer plane stacking height, lower carbon content, higher nitrogen content, and lower electrical resistivity. According to apparent studies, the formation of closed pores from open pores in carbon films occurred at 1100 C during the carbonization process.

## Acknowledgements

Professor Ko also is especially grateful to the National Science Council of the Republic of China for its financial support of this project (No#: NSC 84-2216-E035-01).

## Reference

1. T. H. Ko, H. Y. Ting, and C. H. Lin, *J. Appl. Polym. Sci.*, 35, 631 (1988).
2. T. H. Ko, H. Y. Ting, J. C. Chen and C. H. Lin, *J. Appl. Polym. Sci.*, 35, 863 (1988).
3. T. H. Ko, H. Y. Ting, and C. H. Lin, *J. Appl. Polym. Sci.*, 37, 541 (1989).
4. T. H. Ko, *J. Appl. Polym. Sci.*, 42, 1949 (1991).
5. T. H. Ko, P. Chiranairadul, and C. H. Lin, *Polym. Eng. Sci.*, 31, 1618 (1991).
6. S. B. Warner, D. R. Uhlmann, and L. H. Peebles, Jr., *J. Mater. Sci.*, 14, 1893 (1979).
7. H. Marsh, *Introduction to Carbon Science*, Butterworth & Co. Ltd, 1989, p.12.

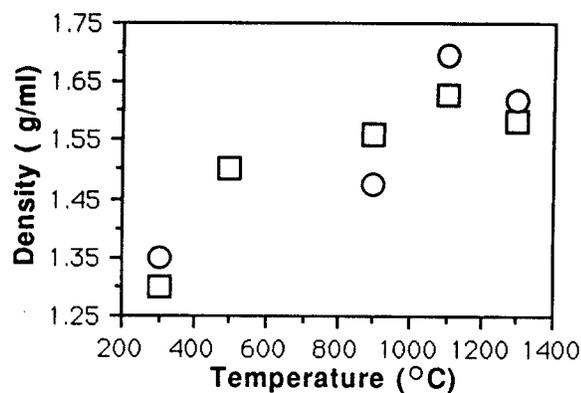


Figure 1 Variation of density of carbon films as function of carbonization temperature: (□) film A, (○) film B

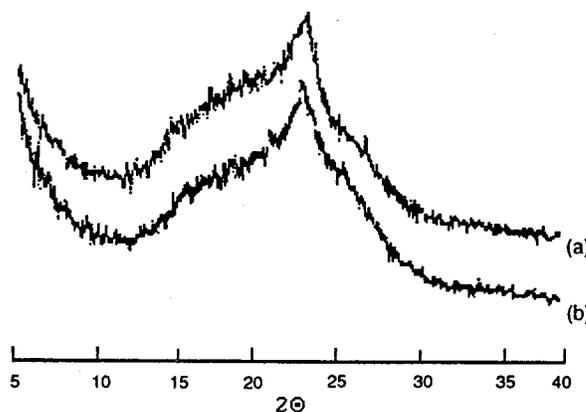


Figure 2 Wide-angle x-ray diffraction pattern of carbon films carbonized at 1300 C for (a) film A, (b) film B

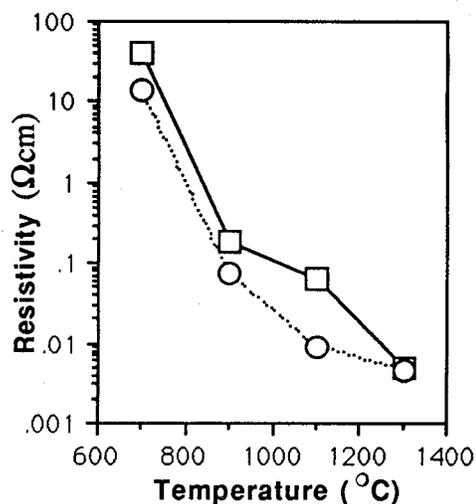


Figure 3 Variation of electrical resistivity at room temperature for carbon films: prepared from: (□) film A, (○) film B