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Development of Orientation in GO/Phenolic Resin-Based Carbon Film

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1 Introduction

The graphite materials possess high electrical and thermal conductivity and high thermal and chemical resistance, which makes them an important class of material in various application fields. The high temperature heat treatment involved in the production process, however, increases the production cost and it is desired to develop a production process at a lower heat-treatment temperature. The present authors have been trying to develop carbon films from polymers dispersed with graphene oxides (GO) through a heat treatment at a lower temperature. By using a resol type phenolic resin for the starting matrix polymer, a carbon film has been derived which shows electrical conductivity twice as high as that of the carbon film derived from a polyimide film "kapton" known to give well-oriented graphite film. [1] The electrical conductivity of GO/resol type phenolic resin-based carbon films is plotted against the mass fraction of GO in Fig. 1. In the present study, development of the orientation of GO in the resol type phenolic resin during film drying process, which is considered to be a key factor leading to the high electrical conductivity of GO/resol type phenolic resin-based carbon films, has been investigated by using the synchrotron radiation X-ray small-angle scattering (SAXS).

2 Experiment

A resol type phenolic resin was dissolved in N,N-dimethyl formamide (DMF) or ethanol (EtOH), and desired amount of GO is added to this solution. The SAXS measurements were performed at intervals during film drying process using the facilities at PF, BL-6A. The X-ray wavelength was 0.15 nm, the sample-to-detector length was 1.5 m and Pilatus 3 was used for the detector.

3 Results and Discussion

Fig. 2 shows the SAXS patterns of GO/resol type phenolic resin films before and after drying. The film plane is in parallel to the horizontal direction of the patterns. The scattering pattern changed from the isotropic pattern before drying to the anisotropic pattern after drying, the latter indicating that GO were preferentially oriented in parallel to the film surface. The degree of orientation of GO in the films is shown in the table of Fig. 2.

The orientation of GO in the films was higher when GO with a smaller size, the solvent with a lower vapor pressure (DMF as compared with EtOH) and room temperature (RT) drying were used. These results show that the slower drying and smaller size of the GO are preferable for developing the higher orientation of GO.

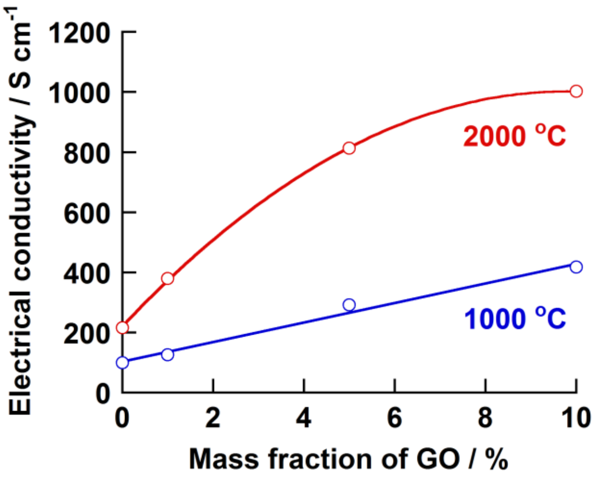
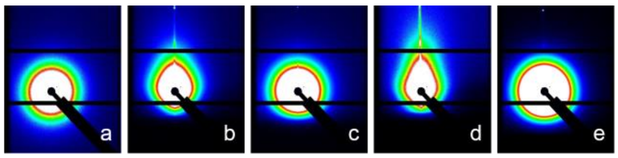


Fig. 1: Electrical conductivity of GO/resol type phenolic resin-based carbon films vs. mass fraction of GO. Carbonization temperatures were 1000 and 2000 °C.



SAXS pattern	GO size (μm)	Solvent	Drying conditions	Degree of orientation
a	4	DMF	Before drying	0.00
b	4	DMF	70 °C, 2 hrs	0.49
c	50	DMF	70 °C, 2 hrs	0.18
d	4	EtOH	RT, 3 hrs	0.64
e	4	EtOH	70 °C, 1 hrs	0.01

Fig. 2: SAXS patterns of GO/resol type phenolic resin films before and after the films were dried under various conditions shown in the table. The degree of orientation of GO in the films is shown in the table.

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References

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