ELASTIC CARBON FOAM/SILICONE COMPOSITE AS A HEATER AT AN AMBIRNT TEMPERATURE

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Introduction

Graphite sheets and carbon fibers are known to be flexible carbon materials, while bulk carbons have been known to be rigid materials. Recently, however, a melamine foam was reported to become an elastic carbon foam [1]. In the present study, we focused on the elastic property and electric conductivity of the carbon foam derived from melamine foam, and prepared a carbon composite with elasticity using silicone. Usefulness of the composite as a flexible heater at an ambient temperature was investigated.

Experimental

A commercially available melamine foam was used. The melamine foam was cut into the sizes of 70 x 30 x 20 mm^3. The bulk specimen was heated at 200°C for 1h in vacuum, and then heated to 900 or 950°C in high purity Ar gas with a heating rate of 20 °C/min and kept for 30 min at each temperature. The carbonized foams were permeated with liquid silicone and then solidified at 130°C for 70 min in air. The liquid silicone used was KE-1842A produced by Shinetsu Chemical Co. Ltd. Both ends of the obtained carbon foam/silicone composite with elasticity were cut, and the fresh cross sections were connected to copper plate electrodes with silver paint. The length of the composite was able to change by changing the distance between the copper plate electrodes. A constant electric current was flowed the composite and the voltage between the electrodes was measured. The temperature was determined using thermocouples contacted to the center of the rectangular surface of the composite after the temperature was stabilized at a constant electric power.

Results and Discussion

Figure 1 shows the XPS spectrum for the melamine foam. Na and S were detected. Na seems to be due to sodium carbonate which was used during foaming process of melamine resin $(C_4N_6H_3)n$. The yields of carbon foams were about 6- 7 wt%. For the 900°-treated foams, Na was also detected (0.6~0.7at%) as well as C (91 ~ 93 atm%)、O (3atm%) and N (3~5 atm%).

The SEM images of the cross sections of the original melamine foam and carbon foam heat treated to 900°C are shown in Fig. 2 (a) and (b). The foam shrank 80% in length but maintained the shape, and the texture also shrank. The high magnification SEM images of the cross sections of the carbon foam and the carbon foam/silicone composite are

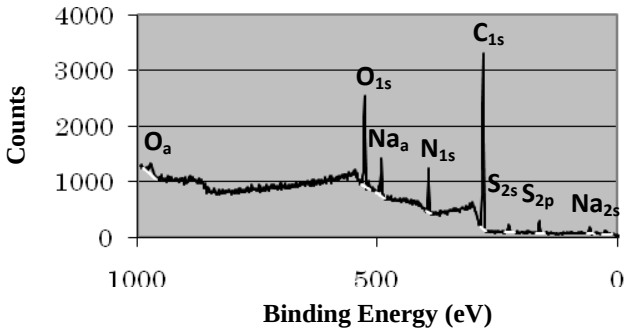

Fig. 1 XPS spectrum for a melamine foam.

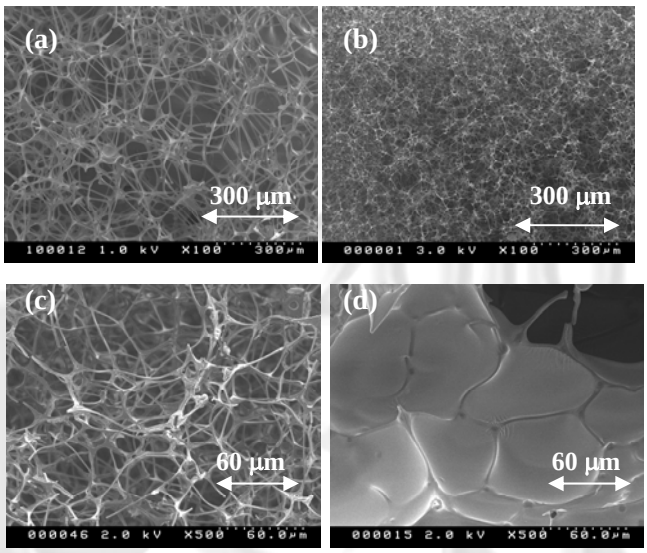

Fig. 2 SEM images of original melamine foam (a) and carbon foam heat treated to 900°C (b), (c) and the carbon foam/ silicone composite (d).

shown in Fig. 2 (c) and (d). The texture of the carbon foam is fibrous network, rather than foam. Silicone filled the carbon foam and the wettability of silicone to carbon seems to be good. It can be estimated from the weight change and Fig. 2 (d) that 99% in weight and volume of the carbon foam/ silicone composite is silicone.

Figure 3 shows the plots of the voltage V and resistivity ρ as a function of applied current I for the 900 °C-treated carbon foam/ silicone composite. A linear dependence of V on I, i. e., Ohmic dependence, was obtained. The resistance of the composite was 330 Ω and ρ is almost constant about 1.3 Ω·m in the temperature region measured.

Surface temperature T of the 900 °C-treated carbon foam/ silicone composite is plotted as a function of electric power applied W in Fig. 4. The temperature increased linearly with increasing applied electric power. The results indicate that

the surface temperature of the composite can be controlled simply by changing the applied electric power.

As shown in Fig. 5, similar results were obtained on the relation between V and I and also that between T and W for the 950 °C-treated carbon foam/ silicone composite except that the resistivity was as low as 0.23Ω.m.

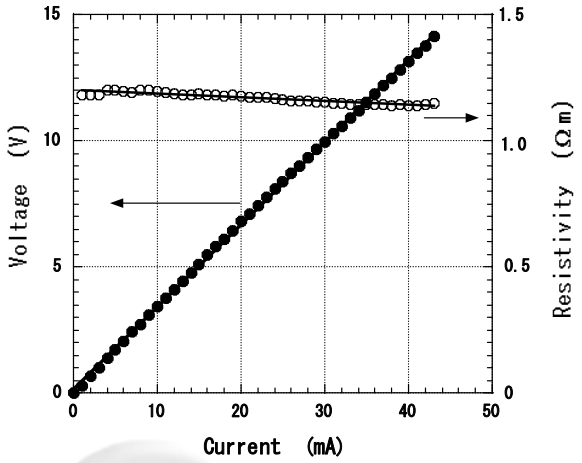

Fig. 3 V-I curve and relation between resistivity and current for 900 °C-treated carbon foam/ silicone composite.

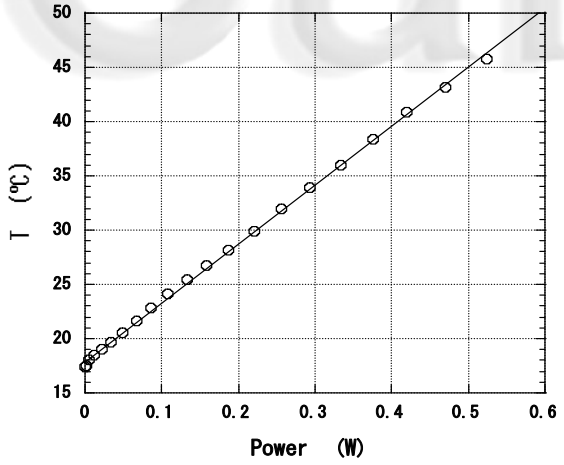

Fig. 4 Surface temperature T of 900 °C-treated carbon foam/ silicone composite as a function of electric power applied W.

The resistivity change of the composites with shrinkage and elongation by changing the distance between the copper plate electrodes was examined. The resistivity increased with both shrinkage and elongation, though the appearance did not change. The resistivity increased further by the cyclic loads of shrinkage and elongation. The fibrous carbon network in the composite is elastic, but the mechanical strength is weak. The conducting pass of the carbon network seems to be damaged gradually by the cyclic loads of shrinkage and elongation.

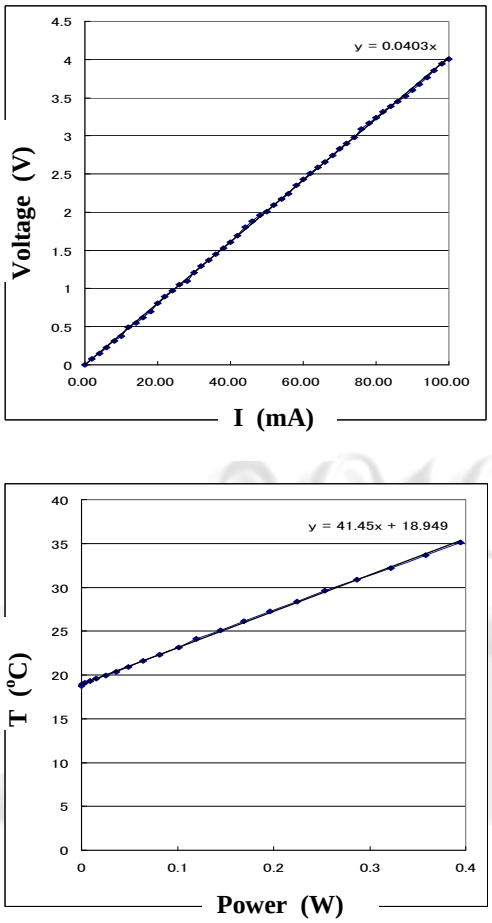

Fig. 5 V-I curve (a) and surface temperature T as a function of electric power applied W (b) for 950 °C-treated carbon foam/ silicone composite.

Conclusions

An elastic carbon foam was prepared from a melamine foam and used for a carbon foam/silicone composite with elasticity. The resistivity of the composite was almost constant below 50°C and the surface temperature increased linearly with applied electric power.

Acknowledgment

We are grateful to Dr. J. Kodama of AIST, Japan, for providing us the melamine foam used in this study.

Reference

[1] Kodama, J. Yamashita, Y. Soneda, H. Hatori, K. Kamegawa, Carbon 2007; 45: 1105-1136.