Rheological, Morphological and Electrical Properties of Polycarbonate/Multi-walled Carbon Nanotube Composites

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Introduction

Development of the polymer/multi-walled carbon nanotube (MWNT) composites has been widely studied because of its superior mechanical and electrical properties since the discovery by Iijima in 1991 [1-15]. The CNT has Young's modulus up to 1 TPa [16] and has very large aspect ratio. Also, the CNT showed high electrical conductivity up to 10^3 S/cm.

In the polymer/MWNT composites, the rheological properties could be changed by the structure of the composites. Pötschke et al. (*Polymer* **2002**, *43*, 3247) reported the increase of the storage and loss modulus of the polycarbonate (PC)/multi-walled carbon nanotube (MWNT) composites at the low frequency region. According to Mitchell et al. (*Macromolecules*, **2002**, *35*, 8825), it has been proposed that the increase of the rheological properties at the low frequency region was related to the network structure of the CNT.

In this study, the rheological and electrical properties of the PC/MWNT composites are reported by the measurements of the dynamic rheology and electrical conductivity, respectively. In particular, the effects of the MWNT functinalization by hydrogen peroxide (H_2O_2) on the rheological and electrical properties of the PC/MWNT composites are reported.

Experimental

A MWNT was supplied by the Iljin Nanotech Ltd. The MWNT was synthesized by chemical vapor grown method. Typical diameter of MWNT ranged from 10 to 12 nm, while length is between 10 and 15 μm. The PC was supplied by LG Chemical Ltd. with the commercial designation of PC 201 15.

The MWNT was treated by H_2O_2 with an aid of the sonication. The 1.0 g MWNT was treated with the 400 ml of H_2O_2 at 50 °C for 90 minutes. The treated MWNT and H2O2 mixture was dried by two different methods: (i) Thermal drying which is the MWNT and H_2O_2 mixture was dried for 12 hours at 80 °C in the drying oven. (ii) Freeze drying which is the MWNT and H_2O_2 mixture was centrifuged for 1 hour, then the mixture was washed with distilled water until the MWNT and H_2O_2 mixture contained almost no acidity (PH 6.0~6.5). Then, the MWNT and H_2O_2 mixture was freeze dried at –60 °C for 72 hours.

For the preparation of the PC/MWNT composites, a total of 10.0 g of PC/MWNT mixture, ranged from 1 to 7 wt%, was dissolved in the 300 ml of tetrahydrofuran (THF) at 60 °C for 6 hours under the sonication process. The PC/MWNT composites were pressed in the hot press at 260 °C.

For measuring the electrical conductivity, the four-probe method was used to eliminate the contact resistance. Four thin gold wires (0.05 mm thick and 99% gold) were attached in parallel on the samples by conducting graphite paint.

Results and Discussion

TEM. Fig. 1 shows the TEM images of the H_2O_2 treated and untreated MWNT. From Fig. 1 (a), the untreated MWNT is shown to entangled and appeared to be aggregated. From Fig. 1 (b) and (c), the entanglement of the MWNT is loosened after treating the MWNT by the H_2O_2. The degree of entanglement of the MWNT is decreased by treating with the H_2O_2, therefore, the H_2O_2 treatment may be used to improve the dispersion of the MWNT in the PC/MWNT composites. In addition, from Fig. 1 (b) and (c), the length of the MWNT is observed to be shortened for the MWNT by thermal drying than that of the MWNT by freeze drying. This behavior may be due to the continuous chopping by the thermal effect.

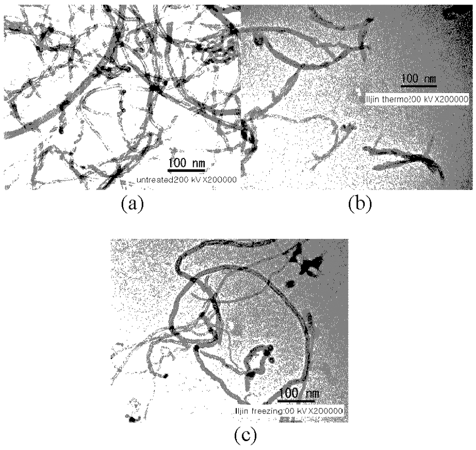

Fig. 1. TEM images of the H_2O_2 treated and untreated MWNT: (a) untreated MWNT; (b) H_2O_2 treated MWNT (by thermal drying); (c) H_2O_2 treated MWNT (by freeze drying).

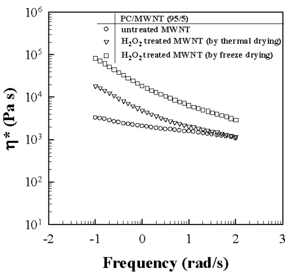

Fig. 2 shows the complex viscosity (η*) of the PC and PC/MWNT composites at 260 °C. For the complex viscosity of the PC/MWNT (95/5, H_2O_2 treated) composites, shear-thinning behavior is observed compared the PC/MWNT (95/5, untreated) composites. The shear-thinning behavior and long time relaxation suggest the pseudo-solid-like behavior of the PC/MWNT (95/5, H_2O_2 treated) composites shown in Fig. 2.

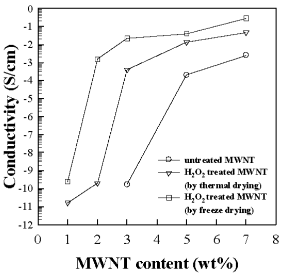

Fig. 3 shows the electrical conductivity of the PC/MWNT composites with the MWNT content. For the PC/MWNT (untreated) composites, the electrical conductivity shows the percolation threshold at about 5 wt% MWNT content. For the H_2O_2 treated MWNT (freeze drying) and H_2O_2 treated MWNT (thermal drying) composites with the PC, the electrical conductivity shows the percolation threshold at about 2 and 3 wt% MWNT content, respectively.

Conclusions

From the above results of the morphological, rheological, and electrical properties of the PC/MWNT composites, it can be concluded that the rheological and electrical properties of the PC/MWNT composites are affected by the MWNT-MWNT network structure which is related with the MWNT morphologies such as the degree of aggregation and aspect ratio of the MWNT.

References

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