

# Mechanical, Thermal, and Electrical Properties of Cellulose Acetate/Multi-walled Carbon Nanotube Nanocomposites Prepared by Melt-Compounding

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## 1. INTRODUCTION

Because of the energy crisis and environmental problems, eco-friendly biodegradable polymers from renewable resources have attracted great attention with expertise in diverse areas. As a renewable source-based biodegradable polymer, cellulose acetate (CA) is a kind of thermoplastic material produced by the esterification of naturally abundant cellulose materials such as cotton, wood pulp, sugarcane, and recycled paper. Owing to potential compostibility, excellent optical and mechanical properties, CA has been used for the applications in diverse areas such as fibers, films, laminates, adhesives, coatings, plastic products, etc.

Polymer nanocomposites are commonly defined as the combination of a polymer matrix and additives that have at least one dimension in the nanometer range. The additives can be one-dimensional (nanotubes and fibers), two-dimensional (clay and graphite), or three-dimensional (spherical particles). Adding such additives to polymers can effectively enhance the properties of composites such as strength, modulus and thermal stability. Carbon nanotube (CNT) is one of the nano-additives and considered as ideal reinforcing nanofiller for polymer matrix due to its unique mechanical property, thermal stability, high aspect ratio, and electrical conductivity. Accordingly, lots of polymer/CNT nanocomposites have been investigated. However, to our knowledge, there have been no reports on nanocomposites based on CA and CNT. In this study, we have prepared CA/CNT nanocomposites by melt-compounding of CA with neat multi-walled carbon nanotube (MWCNT) or acid-treated one (MWCNT-COOH), and investigated their thermal, mechanical, and electrical performances in conjunction with morphological features.

## 2. EXPERIMENTAL

Cellulose acetate (CA) in a powdery form (acetyl content of 39.7 wt%, degree of substitution of 2.45) was supplied from Sigma-Aldrich, Inc. Neat

MWCNT (diameter of 10~15 nm, length of 10~20  $\mu\text{m}$ , and purity of ~95 wt%) was purchased from Hanwha Nanotech Co. Ltd. MWCNT-COOH were firstly obtained by adding neat MWNT in a mixture of sulfuric acid(95%)/nitric acid (3/1 by mol ratio) at 120 $^{\circ}\text{C}$  for 2hrs. Nanocomposites based on CA and MWCNT-COOH were prepared by a melt-compounding method. Before melt-compounding, all the components were dried in vacuum at 80  $^{\circ}\text{C}$  for 24 hrs. For structural characterization and physical properties analyses of CA-based nanocomposites, the melt-quenched films of 0.20 mm thickness were prepared by compression-molding in a hot-plate at 250  $^{\circ}\text{C}$  and 18 MPa for 4 min, quenching into cold water, and dried in the vacuum oven at 60  $^{\circ}\text{C}$  overnight. For comparison, CA/MWCNT composite films were prepared in the same way.

Chemical structure of nanocomposite films were characterized by using Transform Infrared (FT-IR) spectrometer (Tensor 27, Bruker) in an attenuated total reflectance (ATR) mode with a ZnSe crystal. Dispersion state of CNTs in the nanocomposites was examined by a scanning electron microscope (SEM, JEOL-JSM 6380). Dynamic mechanical properties were measured by DMA (TA Q800). Thermal properties were investigated by TGA (TAQ500). Electrical properties were examined by 6517A electrometer/high resistance meter with 8009 resistivity test fixture (KEITHLEY).

## 3. RESULTS AND DISCUSSIONS

Fig. 1 showed FT-IR spectra of pure CA and its nanocomposites reinforced with neat MWCNT and MWCNT-COOH of 1.0 wt%. The pure CA exhibited a strong carbonyl (C=O) stretching band at  $\sim 1738\text{ cm}^{-1}$  due to the existence of acetate groups. FT-IR spectra of the nanocomposites were almost identical with that of the pure CA, except for the band position of carbonyl groups. For pure CA and CA/MWCNT nanocomposite, the C=O stretching band was detected at  $\sim 1738\text{ cm}^{-1}$ , whereas it appeared at  $\sim 1734\text{ cm}^{-1}$  for CA/MWCNT-COOH

nanocomposite. Therefore, it is believed that the shift of the C=O stretching band to lower wavenumber is owing to the specific interaction between carboxylic acid groups of MWCNT-COOHs and carbonyl groups of CA matrix.

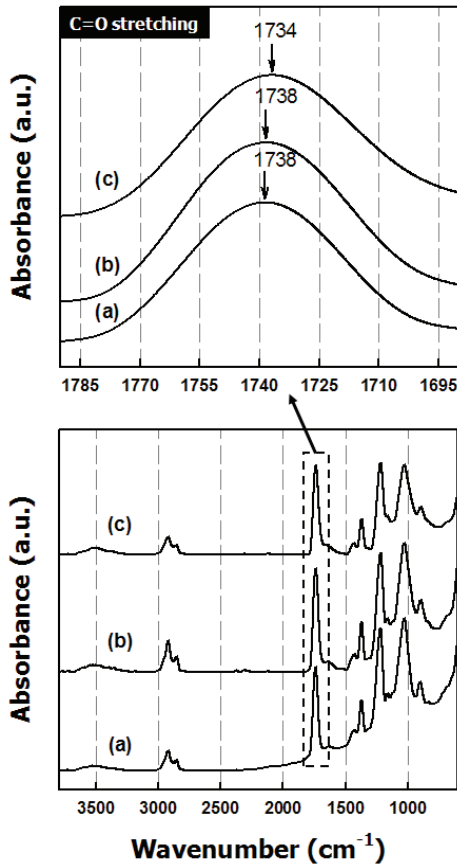


Fig. 1. FT-IR spectra of (a) CA homopolymer, (b) nanocomposite with 1.0 wt% MWCNT, and (c) nanocomposite with 1.0 wt% MWCNT-COOH.

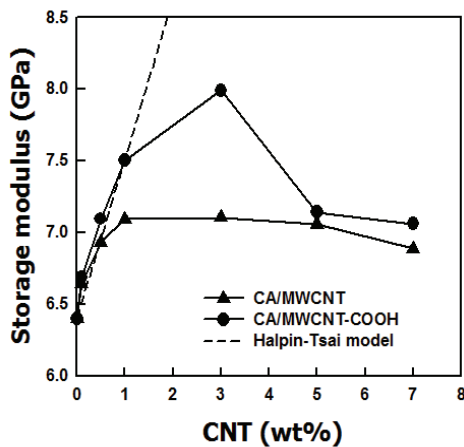


Fig. 2. Comparison of experimental storage moduli at 35 °C for CA/MWCNT and CA/MWCNT-COOH nanocomposites with the moduli predicted by Halpin-Tsai.

Fig. 2 revealed that the storage moduli of CA/MWCNT-COOH nanocomposites were somewhat higher than those of counterparts at the same CNT content. This result is caused by the fact that CA/MWCNT-COOH nanocomposites have better interfacial adhesion owing to the existence of specific interaction between MWCNT-COOHs and the CA matrix. Therefore, the external stress is effectively transferred from the CA matrix to reinforcing CNTs through the better bonded interfaces in CA/MWCNT-COOH nanocomposites.

#### 4. CONCLUSIONS

In this study, CA-based nanocomposites with various MWCNT contents were prepared via melt-compounding method and their morphology, thermal stability, mechanical and electrical properties were investigated. To enhance the dispersity of MWCNTs and the interfacial interaction between MWCNTs and the CA matrix, acid-treated MWCNT (MWCNT-COOH) was prepared. FT-IR spectra of CA/MWCNT-COOH nanocomposites demonstrates that a specific interaction exists between carboxyl groups of MWCNT-COOHs and ester groups of CA, which leads to better interfacial adhesion between MWCNT-COOHs and CA matrix than CA/MWCNT nanocomposites. Accordingly, thermal stability and dynamic mechanical properties of CA/MWCNT-COOH nanocomposites were higher than those of CA-based nanocomposites including neat MWCNT. On the contrary, electrical volume resistivities of CA/MWCNT-COOH nanocomposites were found to be slightly higher than those of CA/MWCNT nanocomposites, which was attributed to the deterioration of graphene structures for MWCNT-COOH as well as the good dispersion of MWCNT-COOHs in the CA matrix.

#### 5. ACKNOWLEDGEMENTS

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#### 6. REFERENCES

[1] Scott G, *Polym Deg Stab* 68:1 (2000).  
 [2] Sassi JF and Chanzy H, *Cellulose* 2:111 (1995).  
 [3] Saka S and Ohmae K, *J Appl Polym Sci* 62:1003 (1996).