ROLES OF NI/CNTS HYBRIDIZATION ON RHEOLOGICAL AND MECHANICAL PROPERTIES OF CNTS/EPOXY NANOCOMPOSITES

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1. Introduction

The reinforcement of polymer matrices by particulate filler materials has been studied in depth in numerous investigations. It is generally accepted that its success, to a large extent, depends on the filler-matrix physical interactions that determine the degree of adhesion at the interfaces. These interactions turn on the filler surfaces' active functional groups, surface energy, and energetically different crystallite faces [1].

A key issue in producing high-performance CNTs-reinforced nanocomposites is the ability to control the dispersion of the CNTs in polymeric matrices. Therefore, an understanding of the rheological behavior of the composites is critical. Moreover, rheological studies of thermosetting polymers can be used to gain a fundamental understanding of the cross-linking kinetics and mechanical behaviors of systems. Rheological properties such as the viscosity and the dynamic modulus can be correlated directly with the evolving physical and mechanical properties of a system during a cure process [2,3].

In this work, nanoscaled nickel particles were introduced onto the surface of MWCNTs in order to investigate the effects of the presence and the content of metal on the mechanical interfacial properties and rheological behavior of the MWCNT-reinforced epoxy matrix nanocomposites.

2 Materials and methods

MWCNTs produced by a chemical vapor deposition (CVD) process were obtained from Nanosolution Co. of Korea. The properties of the MWCNTs were as follows: purity>95 wt.% and an average diameter of 10~25 nm. The epoxy resins used in this study were DGEBA, supplied by Kukdo Chem. of Korea (YD-128), which had an epoxide equivalent weight (EEW) of 185~190 g/eq and a density of about 1.16 g/cm^3 at 25℃. 4,4'-diamino diphenyl methane (DDM) was used as a curing agent for the epoxy resins.

For the electroless nickel plating used here, nickel chloride ($NiCl_2 \cdot 6H_2O$) and sodium hypophosphite ($NaH_2PO_2 \cdot H_2O$) were used respectively as the molten salt and the reducing agent in this system. 0.8 wt.% of the Ni/MWCNTs was manually suspended in an epoxy matrix, stirred for 30 min at 80℃, and then sonicated for 30 min to enhance the dispersion state of the Ni/MWCNTs in the epoxy matrix. A curing agent was added to the mixtures at a temperature of approximately 80℃. The mixtures were degassed for 30 min in a vacuum oven, subsequently injected into a mold, and finally cured at 150℃ for 2 h.

3. Results and discussion

Figure 1 gives the shear viscosity as a function of the shear rate for the epoxy resin and resin suspensions containing Ni/MWCNTs. As shown in Figure 1, shear thinning behavior was observed in each resin suspension with Ni/MWCNTs such that the viscosity was reduced with an increase in the shear rate. The addition of a small amount of (0.8 wt.%) of Ni/MWCNTs induced a small increase in the viscosity.

In MWCNT-reinforced polymer matrix composite systems, the dispersion of CNTs is

one of the key points to determine the final mechanical properties of the composites, as mentioned above. Normally, strong filler-matrix interaction can ensure good dispersion of the fillers in the matrix. In this work, the viscosity of the resin suspensions increased as the nickel content increased on the MWCNTs. This result indicates that the dispersability of the MWCNTs in the epoxy matrix was enhanced in the presence of nickel particles. Previous work by the authors showed that the presence of nanoscaled nickel particles on the carbon fibers led to good interfacial adhesion between the fibers and the epoxy matrix. In a similar aspect, the presence of nickel particles on the MWNCTs induced an increase in the viscosity of Ni/MWNCTs mixed into epoxy suspensions.

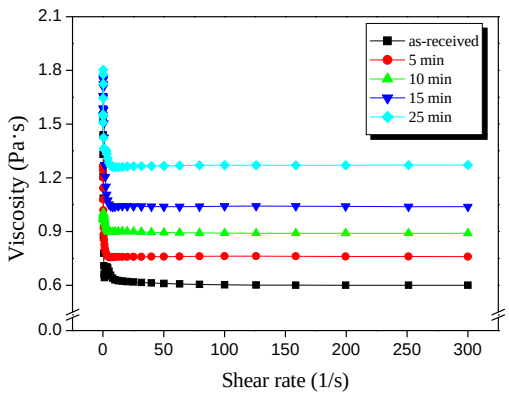
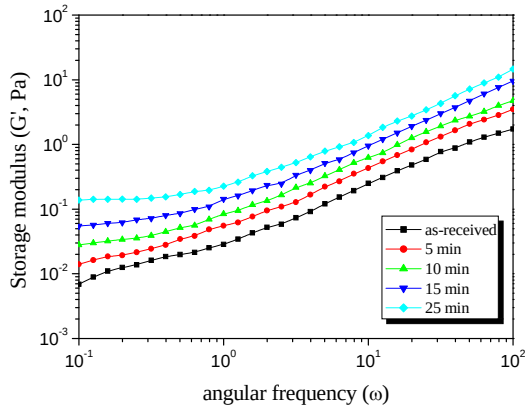
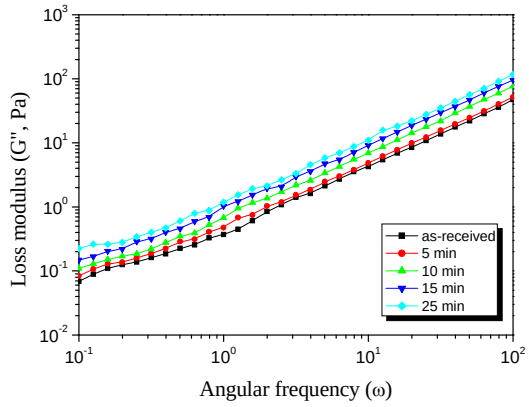


Fig. 1. Viscosity behaviors of Ni/MWCNTs-reinforced epoxy nanocomposites

Figure 2 shows the storage (G') and loss (G'') moduli of the Ni/MWCNT-reinforced epoxy matrix nanocomposites measured with respect to the angular frequency. As shown in Figure 2, the variation in the storage (G') modulus as a function of the nickel content is larger than that of the loss (G'') modulus, indicating that the suspension state is a viscous liquid. Both the storage (G') and loss (G'') moduli of the CNT/epoxy suspensions increase monotonically for all frequencies. This indicates that the viscosity of the suspension is enhanced as the nickel content on the MWCNTs increases due to the good dispersion of Ni/MWCNTs in the matrix and the superior adhesion strength between the Ni-CNTs and the epoxy in this work.



(a)



(b)

Fig. 2. Storage (a) and loss (b) moduli of Ni/MWCNTs-reinforced epoxy nanocomposites measured with respect to the angular frequency

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