

Mechanical Properties of MWNT-Rubber Composite

Weerachai Sangchay¹, Lek Sikong^{1,2} and Kalayanee Kooptarnond^{1,2}

¹Department of Mining and Materials Engineering, Faculty of Engineering, Prince of Songkla University, Hat Yai, Songkhla 90112, Thailand

²NANOTEC Center of Excellence at Prince of Songkla University, Hat Yai, Songkhla 90112, Thailand

*Corresponding author. E-mail: lek.s@psu.ac.th

ABSTRACT

The natural rubber (NR)-multi walled carbon nanotubes (MWNT) composite were prepared by melt mixing of compounding ingredient using two-roll mill. The effect of MWNT loading was investigated. MWNT of 5 phr content enhance the tensile strength and elongation up to 54.64% and 14.22%, respectively. Compression set, tear resistance, modulus and hardness of the NR composite increase with an increase in MWNT loading while scorch time, cure time and %swelling in toluene and oil decrease with an increase in MWNT loading.

Key words: Natural rubber composite, Nanocomposite, Mechanical properties and MWNT natural rubber composites

INTRODUCTION

Since the discovery of carbon nanotubes (CNT) in 1991 (Iijima,1991), CNT have attracted growing interest due to their exceptional mechanical, electrical, and thermal properties (Ajayan, 2000; Fiedler et al., 2006; Guo et al., 2005; Kim et al., 2006; Lee et al., 2007; Merkoci, 2006; Moulton et al., 2006; Natsuki et al., 2004; Paradise et al., 2007; Salvetat et al., 1999; Vaisman et al., 2006 and Yeetsorn, 2004).

CNT have been attracting great interest due to their wide scope of possible applications, such as composite reinforcement material, hydrogen containers, field emission sources, super-capacitors, molecular sensors and scanning probe tips (Paradise et al., 2007 and Vaisman et al., 2006). One potential application of CNT is in the development of CNT-based composites since the inclusion of CNT within various matrices can obviously improve their physical properties (Ajayan, 2000; Fiedler et al., 2006; Lee et al., 2007; Natsuki et al., 2004; Paradise et al. and Shanmughara et al., 2007). Such as the addition of only 1 %wt. CNT to polystyrene results in an increase of elastic modulus and strength by approximately 35%-42% and 25%, respectively (Natsuki et al., 2004).

Natural rubber (NR) is an important material used in wide assortment of engineering applications. Its use depends mainly on its inherent soft and highly

deformation nature. In this paper, NR-MWNT composite were prepared by melt mixing of compounding ingredient using two-roll mill, and their structure and mechanical properties were studied in detail.

MATERIALS AND METHODS

Materials

The NR latex (solid content of 60%) was supplied by Chalong Latex Industry Co., Ltd (Thailand) and multi walled carbon nanotubes (MWNT) produced by the chemical vapor deposition (CVD) obtained from Chiang Mai University are the main starting materials. MWNT purity is over 95%, the length and diameter are greater than 10 μm and 20-50 nm, respectively (Singjai et al., 2007) as can be seen in Figure 1.

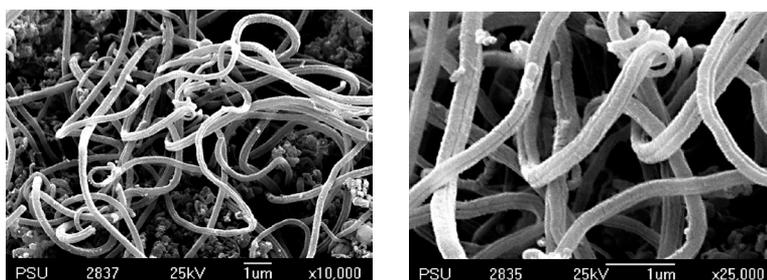


Figure 1. SEM photographs of MWNT.

NR-MWNT composites preparation

The NR latex containing water was vigorously stirred for a certain period of time. After that, the mixture was co-coagulated in the solution by using 1% dilute acetic acid, washed with water and dried in an oven at 80°C for 16 h, and then the dried NR (uncured) was obtained.

Table 1 shows the formulation used in this study. The ingredients, MWNT and other additives were mixed into the dried NR with a 6-in. two-roll mill at room temperature.

Table 1: Recipe of the NR compound.

Ingredients	Contents (phr*)
NR	100
MWNT	Varied
Zinc oxide (ZnO)	5.0
Stearic acid (SA)	3.0
Benzothiazyl disulfide (MBTS)	1.0
Tetramethyl thiuram disulfide (TMTD)	0.5
Sulfur (S)	2.0

*phr is the abbreviation of weight parts per 100 weight part rubber.

Curing characterization

Curing characteristics were studied using a Monsanto Moving Die Rheometer (MDR 2000) according to ASTM D 2240-93. Samples (~ 4g) of the respective compounds were tested at the vulcanization temperature of 150°C.

Vulcanization process

Rubber sheets (1 mm thick) were compressed by stainless steel mold at 150°C with force of 10 MPa, using a hot press according to respective cure times (t_{90}) determined by the MDR 2000.

Swelling study

Swelling was done in toluene during 3 days at room temperature and in oil (SAE 15W-40) during 7 days at room temperature. The tested samples or specimens with the diameter of 12.7 mm and the thickness 6 mm were weighed. The percentage of swelling was calculated using the following equation,

$$\% \text{ Swelling} = \frac{m_1 - m_0}{m_0} \times 100 \quad (1)$$

where m_0 is the mass of specimen before immersion (g)

m_1 is the mass of specimen after immersion (g)

Mechanical properties

Tensile and tear properties were determined using an Instron universal testing machine (5655 series) following ISO 37 (type 1) and ISO 34, respectively. Hardness was measured using hardness machine according to ASTM D2240. The compression set was investigated according to ASTM D471 (method B) at room temperature (25°C) and 70°C for 22 h.

RESULTS AND DISCUSSION

Curing Characteristics

Figure 2 (a) shows that an increase in the MWNT loading into NR compounds reduced the scorch time. This is because of the presence of cross-linked precursors and un-reacted curative in MWNT (Ismail et al., 2002.). Increasing in the MWNT loading into NR compound also reduced the curing time (t_{90}) as shown in Figure 2a. Similar behaviors were also observed by previous research of Ismail et al., 2002.

Swelling behaviors

It can be seen from Figure 2b that percentage of swelling when soaking decreased with an increase in MWNT loading in toluene and oil. This is because of the filler adding in matrix which reduced NR content (MWNT solid filler could not swell) (Rakchonlati et al., 2004).

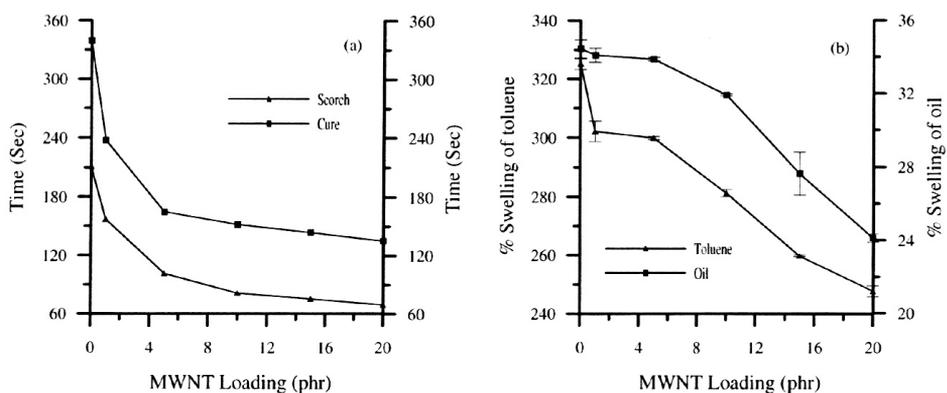


Figure 2. Properties of NR-MWNT composites (a) curing characteristics and (b) swelling.

Mechanical properties

An increase in the MWNT loading in NR increased the compression set (Figure 3 (a)). This is due to the reduction in the elasticity of NR composites with an increase MWNT (Thongsang et al., 2006).

Figure 3 (b) shows tensile strength and elongation properties of the NR-MWNT composites. The MWNT loading in NR seem to increase the tensile strength and reached the optimum value at MWNT loading of 5 phr due to well-dispersed MWNT (Figure 4) and a good interface between the MWNT and NR matrix (Fakhru'l-Razi et al. and Yue et al., 2006). The maximum tensile strength and elongation of composites were 54.64% and 14.22%, respectively. However, the tensile strength and elongation of the composite decrease gradually when MWNT was loading more than 5 phr. This is believed to be caused by the premature failure starting at the MWNT aggregates (Xiao et al., 2007).

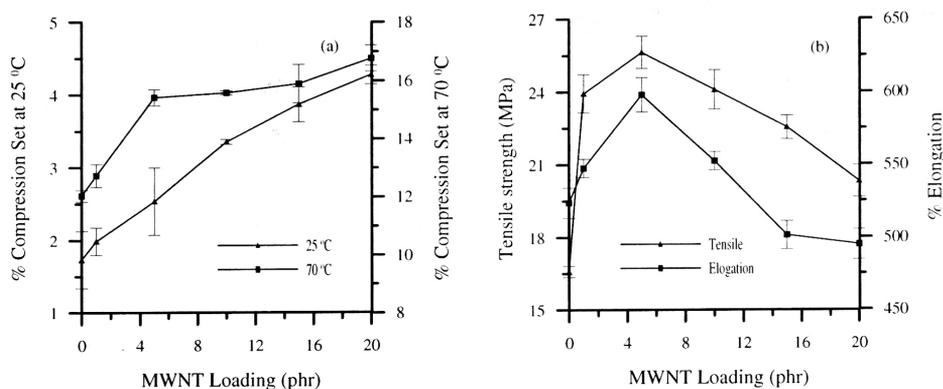


Figure 3. Mechanical properties of NR-MWNT composites (a) compression set and (b) tensile strength and elongation.

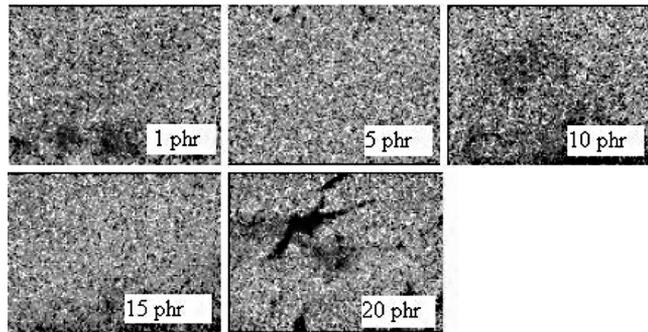


Figure 4. X-ray mapping of NR-MWNT composites showing MWNT dispersion in NR matrix.

Tear resistance, modulus and hardness of the NR composite also increased with an increase in MWNT loading (Figure 5). The increase in tear resistance and modulus of the composite might be attributed to the reinforcement of the well-dispersed MWNT with high Young’s modulus and strength in the NR matrix (Zhou et al., 2006). The increase in hardness was due to an incorporation of hard MWNT into softer NR matrix (Rakchonlat et al. 2004). Similar behaviors were also observed by previous research of Yue et al., 2006.

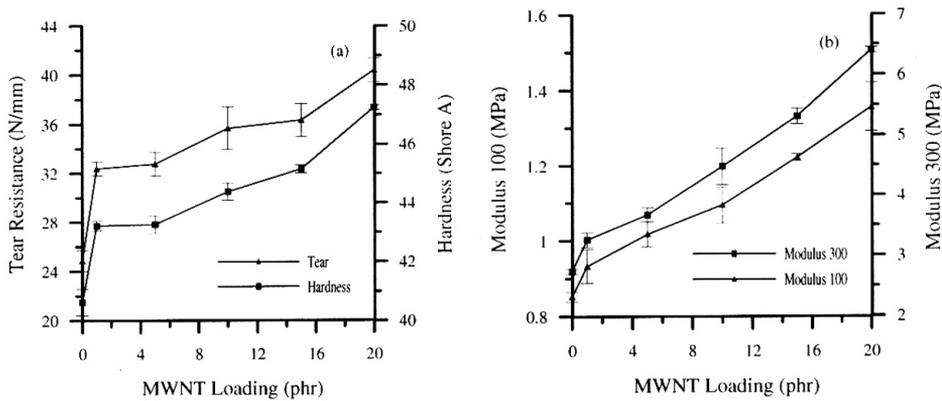


Figure 5. Mechanical properties of NR-MWNT composites (a) tear and hardness and (b) modulus.

CONCLUSION

Curing characteristics such as scorch time and cure time of the NR reinforced with MWNT decreased with increasing MWNT loading. The %swelling of NR-MWNT composites in toluene and oil decreased with increasing MWNT loading. Tensile strength, tear resistance, modulus and hardness significantly increased with increasing MWNT loading. The tensile strength, elongation and modulus of the NR-MWNT composites obtained in this investigation were found to be better

than the previous results (Kim et. al. 2006 and Shanmugaraj et. al. 2007). The tensile strength increased up to 54.64%, when MWNT loading reached 5 phr. This indicated an effective reinforcement of the MWNT. Tear resistance and hardness of the composites increased to the maximum values with increasing MWNT loading to 20 phr.

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