

MECHANICAL AND ELECTRICAL PROPERTIES OF FUNCTIONALIZED MULTI-WALLED CARBON NANOTUBES REINFORCED POLYETHYLENE COMPOSITE FABRICATED BY EXTRUSION SHEAR FLOW

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Introduction

The outstanding mechanical properties of CNTs are due to the high strength of the constituent carbon-carbon bonds and their near perfect lattice structure. Their extremely high strength to weight ratio (10~60 GPa), high Young's modulus (~1 TPa), high electrical conductivity (1.85×10^5 S/cm), and high thermal conductivity ($3000 \text{ Wm}^{-1}\text{K}^{-1}$) give promising potential as a reinforcement material in high performance advanced composites [1,2]. There are few main topics that are currently focusing to improve the properties of CNTs reinforced polymer composites. These topics are dispersion and interfacial bonding strength of the CNTs in polymer matrix [3,4]. Dispersion of CNTs in polymer matrix by ultra sonic wave is reported to achieve greater nano dispersion than with a mechanical stirrer [5]. Chemical functional groups create repulsive forces, which prevent from agglomeration of CNTs [6,7]. There are a few attempts to study the effect of additional CNTs on the mechanical properties of PE composite [8,9].

Experimental

Materials

The polymer matrix is a PE (pellet form) obtained from Sigma Aldrich has 0.93 g/mL density, 15,000 molecular weight (Mw) and 112°C melting point. The reinforcement filler are Multi-walled carbon nanotubes (MWCNTs), purchased from ILJIN Nanotech (South Korea). It has 5~10 nm diameter, 10~20 μm length and 95 % purity, reported by manufacturer. In this study, CNTs are classified into four types: (i) as produced; (ii) carboxylated; (iii) octadecylated; and (iv) surfactant additive MWCNTs. Characterizations of MWCNTs were conducted by Scinco STA S-1500 Simultaneous Thermal Analyzer. Weight concentrations of MWCNTs used in this study were 0.1, 0.5, and 1.0 wt%. MWCNTs powder were added to the PE pellets, and mixed mechanically by spatula for 5 minutes. Then, the PE pellets mixed with MWCNTs were melted at 150°C for an hour,

followed by the degassing process in vacuum oven at 150°C for 3 hours. Then, the molten PE suspension containing MWCNTs was poured to the mould, and pressed at 10 kg cm^{-2} pressure and 125°C for 2 minutes by a hot press.

Results and Discussion

Non-conductive PE polymer becomes conductive by addition of as produced and surfactant additive MWCNTs, as given in Fig.1(a). The electrical conductivity of PE composite is increased with increasing the MWCNTs loading concentrations. However, carboxylated and surfactant additive MWCNTs PE composites not become conductive until 1.0 wt% loading. This may attribute by unbalance polarity and damage of original chirality of as produced CNTs due to chemical functionalization [10]. Incorporation of as produced CNTs in thermoplastic polymer matrix enhanced thermo-gravimetric property of pure polymer due to high thermal stability of CNTs as mentioned in Fig. 1 (b).

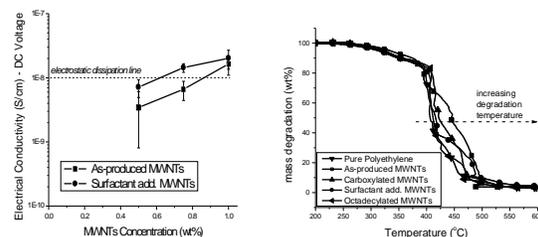


Fig. 1 Variation of (a) Electrical conductivity and (b) Thermal gravimetric analysis of PE nanocomposites.

Mechanical properties results from Fig. 2 below indicate that, there are significant increment of Young's modulus (35%) and tensile strength (30%) of extruded as produced CNTs PE composites at $32,900 \text{ sec}^{-1}$, compared to extruded composites at $1,500 \text{ sec}^{-1}$ shear rate. Detail study about CNTs alignment in polymer matrix induced by shear flow extrusion, and its influence on the mechanical properties of polymer

composites were discussed in details elsewhere [11]. Comparing with related references, it was reported the Young's Modulus at 1.0 wt% as produced MWCNTs PE composites increased at 6% and 3%, respectively, compared to pure PE polymer [9,12]. Refluxed MWCNTs with acid concentration and mixed with dispersant (organic and inorganic) gave 7.0% and 23% increment of the Young's modulus at 1.0 wt% MWCNTs PE composites, respectively, compared to pure PE polymer [10]. In our study, the as produced, surfactant additive, carboxylated and octadecylated MWCNTs PE composites exhibited 60%, 69%, 75% and 96% increase of the Young's modulus at 1.0 wt% loading, respectively. It worthy to note, that our study give the highest Young's modulus increment among the references.

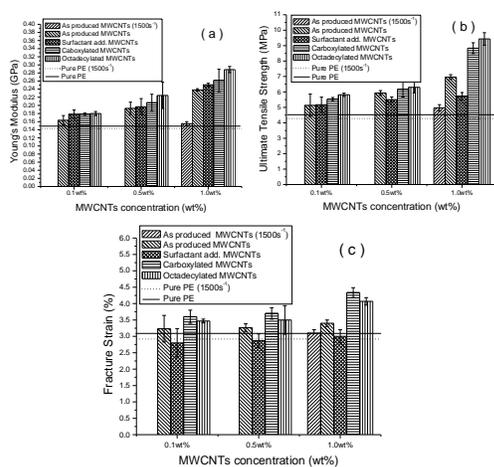


Figure 2. Variation of mechanical properties of MWCNTs PE composites (a) Young's Modulus, (b) Ultimate Tensile Strength, and (c) Fracture Strain

Conclusion

Mechanical strength characterization observation results indicate by introduction of functional groups on the CNTs significantly increases the adhesion strength of CNTs with polymer matrix. Only small amount of mechanical strength improvement is obtained on non-functionalized CNTs composites. However, chemical functionalization lead to decrease of electrical conductivity and thermal degradation properties of as produced CNTs. Defects to physical structure (chirality) of CNTs which occur during functionalization process is main factor for decreasing electrical conductivity. Most of functional moieties on CNTs through chemical functionalization are thermally unstable, lead most of the organic functional groups are decomposed before the onset of CNTs weight degradation. This factor leads earlier thermal degradation of functionalized CNTs than non-functionalized CNTs composites. It can be concluded that chemical functionalization is necessary to

enhance the mechanical properties. However, non-functionalized CNTs are more suitable for electrical applications.

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