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Fabrication and characterisation of low density polyethylene (LDPE)/multi walled carbon nanotubes (MWCNTs) nano-composites☆

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Abstract Carbon nanotubes (CNT) have shown extraordinary electrical, mechanical properties as well as many other physical properties. The aim of this study is to explore the scope of CNT/LDPE nano-composites for engineering applications. Nano-composites of LDPE and MWCNT are generally prepared by using the melt blending method but in the present investigation these have been prepared by using solvent mixing method. Xylene has been used as a solvent which can dissolve low density polyethylene (LDPE) at about 125 °C. The solution of LDPE in xylene has been ultrasonicated with various percentages of MWCNT (0, 1, 2, 5, 10 wt% of MWCNT) composite to form thin film after drying. MWCNT used in this study have been synthesised by electric arc discharge method. Characteristics of these composites have been determined by Raman spectroscopy and scanning electron microscopy (SEM). Raman spectroscopy revealed variation in intensity of CNT's peak with variation in concentration of CNT. The results indicated that intensity of CNT's peak was found to increase with the increase in concentration of CNT which indicated the type of interaction between polymer and CNT. SEM analysis reveals CNT-polymer interfacial adhesion and shows agglomeration of CNT's at some locations and presence of individual tubes at other locations. These investigations show that LDPE/MWCNT composites can be fabricated using simple solvent mixing method. Further investigation on the effect of MWCNT on mechanical, electrical and thermal properties of LDPE based composites are in progress.

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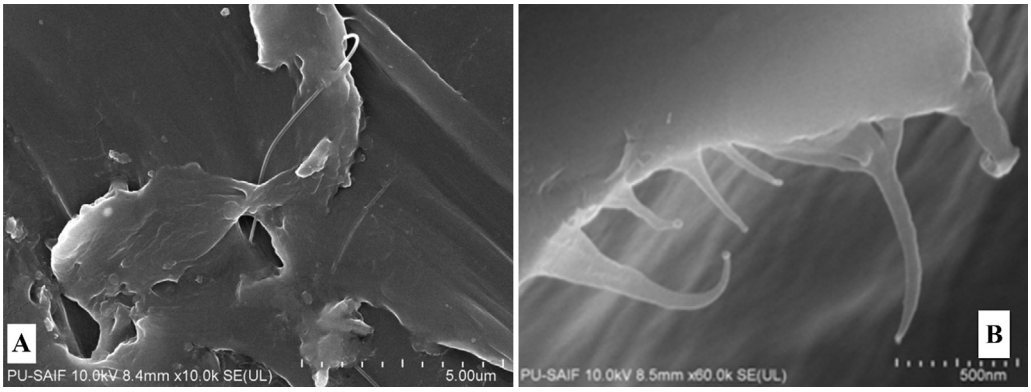

Figure 1 SEM images (A) 1% CNT nano-composite and (B) 10% CNT nano-composite.

Introduction

Carbon nanotubes are members of fullerene family and have a hollow cylindrical structure. Based on the number of graphene layers forming a tube, carbon nanotubes can be classified as single walled and multiwalled carbon nanotubes (Tang et al., 2003). The extraordinary intrinsic properties like high melting point, high mechanical strength (Jindal and Jindal, 2006), high surface area and electrical conductivity (Ebbesen, 1994) and thermal conductivity (Hwang et al., 2004) created a gold rush amongst the researches to explore new potentials of CNT. It has been found that CNT's have a young's modulus of 270—950 GPa and a tensile strength of 11—63 GPa (Saeed, 2013) and high aspect ratio (100—1000) (Abu Al-Rub et al., 2012). The large aspect ratio and high surface area is due to Van der Waals forces of Carbon nanotubes. Dispersion of CNTs in polymers is difficult due to the forces leading to the formation of aggregates. These properties make MWCNT capable for fabrication of nano-composites.

A number of methods have been used for the fabrication of thermosetting polymer/MWCNT composites which consist of: in situ polymerisation (Wang et al., 2006; Xiong et al., 2006) solvent mixing (Ryan et al., 2006; Qu et al., 2004; Ruan et al., 2003) and melt blending method (Zhang et al., 2006; McNally et al., 2005). The tendency to form agglomerates may be less in case of solvent mixing method. Recent studies have shown a significant improvement in mechanical strength of polymer on CNT addition (Jandial and Jindal, 2014). In recent decade there has been a rising curiosity in exploring the behaviours of polymer/CNT nano-composites. Some studies have not only shown a considerable improvement of the mechanical and electrical properties but have also provided many benefits such as flexible features, easy processing, and lightweight (Jin-hua et al., 2012), for instance, Ryan et al. stated that SWCNT's improved the tensile modulus by three times of polyvinyl alcohol matrix. In this study, LDPE/MWNTs nano-composites have been fabricated by using solvent mixing method; in order to investigate the morphology and distribution of MWCNT in low density polyethylene (LDPE) polymer by using xylene as a solvent. This study could be further used to study the mechanical, electrical, thermal properties of the nano-composites prepared in this study

Experimental

Preparation method

Low density polyethylene film grade was used for this study which had been obtained from Indian oil limited. Xylene rectified with 97% purity was obtained from fisher scientific. CNT used in this study has been prepared by liquid arc discharge method having an average diameter of 12 nm.

MWCNT have been prepared by using liquid arc discharge method. The medium used in preparation of MWCNT was sodium chloride solution. Two graphite rods with a purity of 86.5% were used as a electrodes and an arc is produced between them at a current of 50 A and 150 V which produced MWCNT as well some amorphous carbon which was further removed by refluxing the sample with an oxidising agent like nitric acid. MWCNT obtained in this process were around 12 nm in diameter and 1—1.5 μm in length (Goyal et al., 2015).

In this study polymer nano-composites have been prepared using solvent mixing method (Jindal et al., 2014). LDPE was dissolved in xylene by melting low density polyethylene (LDPE) at a temperature of 115 °C in presence of xylene. Simultaneously a measured amount of MWCNT was sonicated in a small quantity of xylene solution. The two solutions prepared were mixed together and were spread

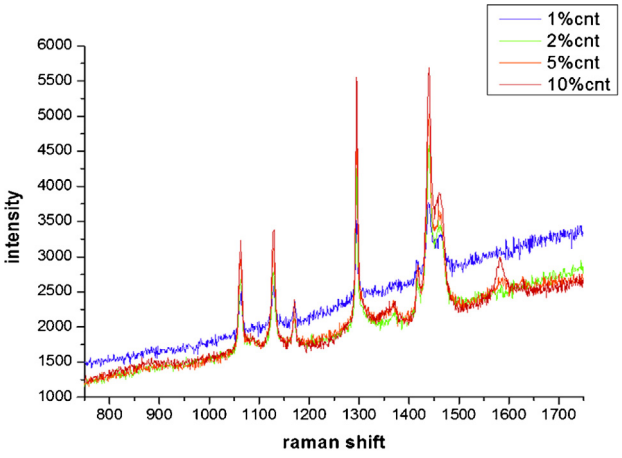

Figure 2 Raman analysis of CNT/LDPE nano-composite.

on a sheet of glass to form thin layers of sheets of polymer nano-composites.

Characterisation

The microstructure of samples have been investigated using Hitachi instruments, Su8010 field emission scanning electron microscopy (FESEM) as shown in Fig. 1A and B. The Raman spectroscopy has been performed on Renishaw micro Raman spectrometer at 785 nm to investigate morphology and distribution of MWCNT in the Nano-Composites as shown in Fig. 2.

Results and discussion

Scanning electron microscopy (SEM)

The surface morphology of LDPE and its nano-composites was investigated by SEM analysis. SEM images of the nano-composites prepared by using 1%, 2%, 5%. 10% MWCNT in these studies are shown in Fig. 1A and B. Mostly there were individual nanotubes spread in the matrix but some of them were clumped together as aggregates. The uniform dispersion of CNT's in LDPE/MWCNT nano-composites is confirmed by SEM analysis. This uniform dispersion could further help in formation of pallets using moulding machine with many future applications.

Raman spectroscopy

Typically carbon nanotubes have two peaks. One which is formed at 1476 cm^{-1} known as the G Band (Graphitic Band) and other is formed at 1295 cm^{-1} known as the D Band (Defects Band) (Jindal et al., 2013). The Raman spectra of nano-composites formed is shown in Fig. 2. The interaction between nanotubes and polymer is reflected by a peak shift or a peak width change (Zhao and Wagner, 2004). Fig. 2 reveals the increase in intensity of carbon nanotube peaks with the increasing carbon nanotube content in the nano-composite. Raman spectroscopy of pure CNT revealed that peaks of CNT were formed at 1385.9 cm^{-1} (D Band) and 1574 cm^{-1} (G Band). Therefore when CNT's were fabricated in LDPE the D Band was found to decrease by 90.9 cm^{-1} and G Band by 98 cm^{-1} which may be due to the interaction between LDPE polymer and CNT's.

Conclusions

Since polymer material is widely used for several engineering applications where low weight is a primary requirement, it becomes imperative that they possess high mechanical strength. In this experimental work we have been able to successfully fabricate the composites of LDPE with high strength MWCNT using simple solvent mixing method. Various characterisation techniques like SEM and RAMAN spectroscopy confirm presence and uniform dispersion of MWCNT in LDPE, thereby enabling these composites to be used for various other mechanical and electrical testing techniques. It is expected that MWCNT will be able to impart sufficient strength to LDPE polymers as well to be used for various other applications.

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