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Preparation and Mechanical Properties of Compositionally Graded Polyethylene/Clay Nanocomposites

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ABSTRACT

This paper presents the preparation and mechanical properties of compatibilized compositionally graded Polyethylene/ low density polyethylene (LDPE)/ modified montmorillonite (MMT) nanocomposites prepared by solution and melt mixing techniques. Use of polyethylene glycol as compatibilizer improves compatibility of modified montmorillonite and low density polyethylene. Comparisons between two techniques show that the melt mixing technique is the preferred method for preparation the Polyethylene/Clay nanocomposites for uniform and compositionally graded distributions. It is observed, the addition of Nano clay improves the mechanical properties like tensile strength. Also, it is noticed the mechanical properties of compositionally graded Polyethylene/Clay nanocomposites are improved rather than the uniform distribution of Polyethylene/Clay nanocomposites. The morphology of nanocomposites cross section samples is studied by Scanning Electron Microscopy (SEM) and finally the comparison are made between two techniques and then between compositionally graded polyethylene/clay nanocomposites with uniform ones. Its show that when the compatibilizer was added for melt mixing technique, the density and the size of the aggregates decreased, which indicates that the dispersion of nano clays within the polymer matrix is much better.

Keywords: Compositionally graded; Polyethylene; Montmorillonite; Solution technique; Melt mixing technique.

1 INTRODUCTION

LINEAR low-density polyethylene (LLDPE) is a versatile material for application in cable and film manufacturing industries. The synthetic polymer process converts the virgin polyethylene to a new material with improved, upper service temperature chemical and environmental stress cracking resistance and electrical properties [1–3]. There has been growing interest in polymer/Nano clay nanocomposites in recent years because of their outstanding properties at low loading levels as compared with conventional composites. It has been observed that adding small quantities of Nano clay to some thermoplastics as a reinforcing filler to form nanocomposite materials has not only led to more improved mechanical and thermal properties, but also to an enhancement of the dielectric strength and partial discharge resistance [4–13]. Zhao et al. [14] studied the properties of PE/clay nanocomposites, which were prepared by melt mixing and found that the mechanical and flammability properties of the polymers

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improved with the clay addition. Huang et al. [15] studied the thermal stability and fire behavior of LDPE/clay nanocomposites, which were prepared by melt mixing, and observed the improved thermal stability and flame retardant. Besides the nature of fillers and their content in the product, the adhesion between matrix and filler and the aspect ratio of the filler are also the key factors in the improvement of the polymer final properties [16]. The present work deals with the preparation and mechanical properties of compatibilized compositionally graded Polyethylene/ low density polyethylene (LDPE)/modified montmorillonite (MMT) nanocomposites prepared by solution and melt mixing techniques. The morphology is studied by Scanning Electron Microscopy (SEM) and comparisons are made between two techniques and also between compositionally graded with uniform polyethylene/clay nanocomposites.

2 EXPERIMENTAL

2.1 Materials

The polymer matrix used in this study was a linear low-density polyethylene with trade name LL209AA from Arak Petrochemical Co. (Iran), with melt flow index (MFI) of $0.9g/10\,min$ and density $\rho = 0.92g/cm^3$. The nanofiller was K10 montmorillonite from Sigma-Aldrich, Germany. It is well known as having a CEC of $70-100meq/100g$. The toluene employed in this study was 108323 toluene from Merk-KGaA, Germany. Finally the polyethylenglycol employed was polyethylenglycol 40 from Merk-KGaA, Germany.

2.2 Processing

2.2.1 Melt mixing technique for uniform distribution (UD)

An internal mixer from Brabender, Germany (model WHT 55), with roller type rotors and mixer capacity of $55cm^3$ was used for preparation nanocomposites samples. The nano clay (MMT) was dried at $40^{\circ}C$ in a vacuum oven for a minimum of $48hrs$. Low density polyethylene (LDPE) and polyethylenglycol were added to the Nano clay. All materials were manually premixed before introduction into the mixer. The outlets products of mixer use for extrusion and the samples were then extruded and cooled to room temperature. The extrusion temperature was set at $140-180^{\circ}C$ from the feeder to the die.

2.2.2 Solution technique for uniform distribution (UD)

The methodology consist the dispersion of Nano clay in the polymer matrix and the removal/evaporation of solvent. The nano clay (MMT) was dried at $40^{\circ}C$ in a vacuum oven for a minimum of $48hrs$. The solvent (Toluene) was heated up to $85^{\circ}C$ before LDPE sample was added into the solvent. Then, LDPE sample was added into the solvent and Low density polyethylene and toluene solution were added to the Nano clay. The temperature used for this solvent was controlled at $80^{\circ}C$ to avoid the boiling of solvent. The mechanical mixture was stirred for 30 *min*. After stirring, the suspension was treated with ultrasound for 20 *min*. Ultrasonic stirring from Hielscher, Germany (model UP400S) were used to ultrasound the suspension. At the end, the suspension was distilled and then, poured into the die.

2.2.3 Melt mixing technique for compositionally graded distribution (CGD)

After the melt mixing procedure, the products were compressed and then moulded into sheets by an electrically heated hydraulic press. The thickness of each sheet is 1 *mm* and four sheets with different nano particles weight percent (pure, 1 wt%, 3 wt% and 5 wt %) were employed to make compositionally graded nanocomposite. The processing of melt mixing technique for compositionally graded distribution is presented in Fig. 1.

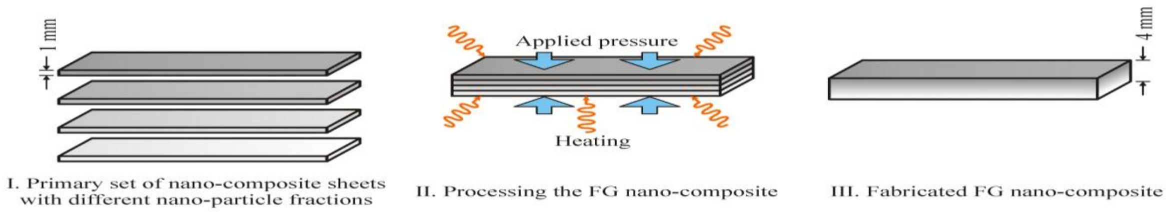

Fig.1
Processing of melt mixing technique for compositionally graded distribution.

2.3 Scanning electron microscope (SEM)

The morphology of nanocomposites cross section samples for uniform distribution was observed by a SERON AIS2300C scanning electron microscope (SEM) after sputter coated with gold. Fig.2 is the SEM photography of nanocomposite for uniform distribution prepared by solution technique and Fig.3 is the SEM photography of nanocomposite for uniform distribution prepared by melt mixing technique. The morphology of nanocomposites cross section samples for compositionally graded distribution was observed by a TESCAN MRIA3 scanning electron microscope (SEM) after sputter coated with gold.

2.4 Mechanical properties

The tensile properties were evaluated according to ASTM D638 using dumbbell-shaped samples and Gotech universal testing machine Model GT-AI5000L tensile tester with a crosshead speed of 50 *mm/min*. The material compositions of the nanocomposites are listed in Table 1.

Table1
Sample compositions.

sample	LDPE (wt %)	Compatibilizer (wt %)	MMT (wt %)
1	85	15	-
2	82	15	3
3	80	15	5
4	78	15	7

3 RESULTS AND DISCUSSION

This study presents the preparation and mechanical properties of compatibilized compositionally graded Polyethylene/ low density polyethylene (LDPE)/ modified montmorillonite (MMT) nanocomposites prepared by solution and melt mixing techniques. Fig. 2 shows that the morphology for solution technique is not homogeneous, which reveals a poor intercalated/exfoliated structure.

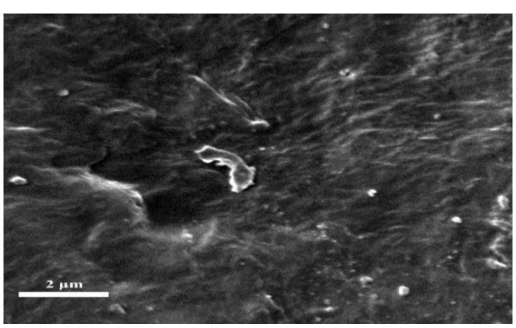

Fig.2
SEM image of nanocomposite prepared by solution technique for uniform distribution.

However, when the compatibilizer was added (Fig. 3), it was observed that the density and size of the aggregates decreased, which indicates that the dispersion of nano clays within the polymer matrix is much better.

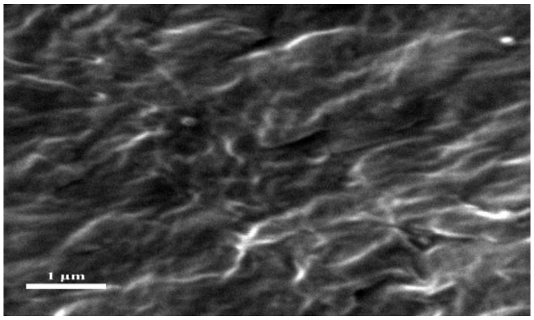

Fig.3
SEM image of nanocomposite prepared by melt mixing technique for uniform distribution.

The comparison between Figs. 2-3 shows that the adhesion of the particles of nano clay and polymer in the presence of compatibilizer is improved. Fig. 4 is the SEM photography of nanocomposite for compositionally graded distribution prepared by melt mixing technique.

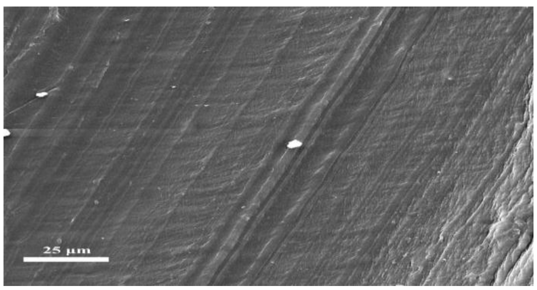

Fig.4
SEM image of nanocomposite prepared by melt mixing technique for compositionally graded distribution.

It seems that the dispersion of nano clays vary smoothly and continuously from one surface to the other one.

Fig.5
Dumbbell-shaped samples.

Fig. 6 shows the effect of nano clay on the yield strength of nanocomposites with different nano particles weight percent.

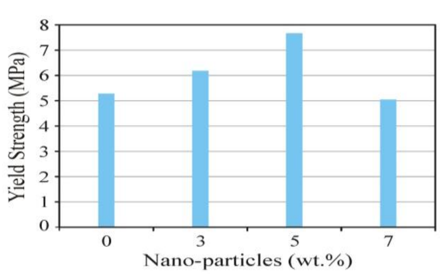

Fig.6
The yield strength of nanocomposites with different nano particles weight percent.

As noticed yield strength begins to increase up to 5 wt% of nano clay. This effect due to existence of strong and sufficient bonding among polymer and nano clay. By increasing the amount of nano clay more than 5 wt% the yield strength is found to level off. The agglomeration may be due to great area to volumes ratio of nanoparticles and their tendency to establish strong bonding among themselves compared to polymer and causes lower tensile properties. Fig. 7 shows the effect of nano clay on the ultimate strength of nanocomposites with different nano particles weight percent.

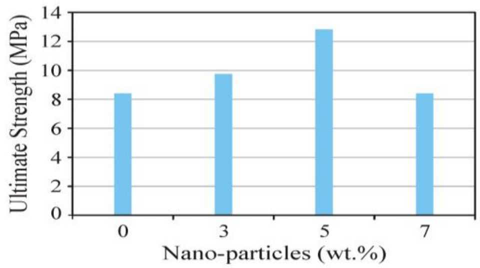

Fig.7
The ultimate strength of nanocomposites with different nano particles weight percent.

Also, the ultimate strength begins to increase up to 5 wt% of nano clay. By increasing the amount of nano clay more than 5 wt% the ultimate strength is found to level off. Fig. 8 illustrates the effect of nano particles with different weight percent on elastic modulus.

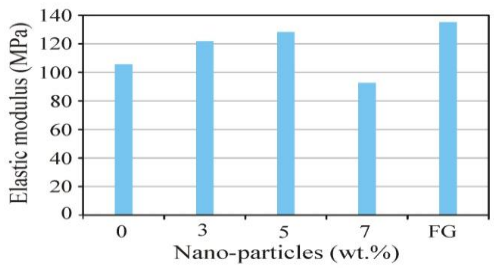

Fig.8
The effect of nano particles with different weight percent on elastic modulus.

It's shown that elastic modulus begins to increase up to 5 wt% of nano clay and then decreases. However for compositionally graded distribution, the elastic modulus is generally larger than the corresponding values for uniform distribution of nano clay.

4 CONCLUSIONS

In the present paper, the preparation and mechanical properties of compatibilized compositionally graded Polyethylene/low density polyethylene (LDPE)/modified montmorillonite (MMT) nanocomposites prepared by solution and melt mixing techniques are presented . Some conclusions are made as follows:

1- The mixing technique is generally better than the solution one for preparation the Polyethylene/low density polyethylene (LDPE)/modified montmorillonite (MMT) nanocomposites.
2- The compatibilizer plays an important role to improve the properties of Polyethylene/low density polyethylene (LDPE)/modified montmorillonite (MMT) nanocomposites.
3- By increasing the nano particles weight percent, the mechanical properties increase up to 5wt%nano clay.
4- The agglomeration may be due to great area to volumes ratio of nanoparticles and their tendency to establish strong bonding among themselves compared to polymer and causes lower tensile properties.
5- The elastic modulus for compositionally distribution of nano clay are generally larger than the corresponding value for the uniform distribution of nano clay.

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