

Preparation and Characterization of High-Density Polyethylene Blends and Recycled Poly(ethylene terephthalate)

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Abstract. Polymer blends based on recycled high density polyethylene (rHDPE) and recycled poly(ethylene terephthalate) (rPET) with two types of ethylene-glycidyl methacrylate copolymer (E-GMA), Lotader AX8840 and Lotader AX8900 as compatibilizer were produced in a co-rotating twin screw extruder. The effects of adding rPET content on the impact properties of rHDPE-rich blends were also investigated. The result showed an enhancement of about 80-270% in impact properties as compared to those of the Lotader AX8900. The impact strength also showed a decreasing trend as the rPET content was increased. The addition of E-GMA to the rHDPE/rPET blends was found to recover the blend toughness as well as improving the compatibility between HDPE and PET. In this study, the highest result was obtained for the rHDPE/rPET blends using Lotader AX8840 composition with 7.5% E-GMA content. FTIR analysis of the compatibilized blends confirmed the chemical interaction and improved interfacial bonding between the two phases.

Introduction

The worldwide annual collection of post-consumer and post-industrial plastic wastes is approximately a few million tonnes per year. There are still a significant amount of plastics end up in landfill despite the recycling capacity for plastic wastes has been progressively increased [1]. In the view of environmental concern, plastic waste recycling not only conserves both virgin materials and energy but also provides a solution to plastic waste disposal [2].

High density polyethylene (HDPE) and poly(ethylene terephthalate) (PET) are extensively used in packaging of consumer and industry products and constitute a significant fraction of post-consumer waste [3]. Consequently, both of HDPE and PET bottles represent a promising recycling opportunity since there is great interest in finding new possibilities for the use of post-consumer plastics as new products [4,5]. Mechanical recycling that involves blending of plastics is one of the attractive recycling method to obtain new materials with superior mechanical properties of blends due to the ease of fabrication, highly convenient and economical advantage reasons [3,5,7].

Regarding the previous studies of HDPE/PET blends, most of the researchers are focused on compatibilization methodologies since HDPE and PET are incompatible in nature due to the great difference in solubility parameters between them [8]. The incorporation of a surface-active species called compatibilizer which concentrates at the interface, tends to improve the interfacial adhesion as well as refine and stabilize the blend morphology [9]. GMA-containing copolymers are the most efficient species as compatibilizer [10]. There are three main chemical aspect reasons for that statement. First, epoxy functionality of GMA ables to react with both hydroxyl and carbonyl end groups of PET, whereas MA reacts only with hydroxyl ends. Second, epoxy function of GMA has higher reactivity than MA towards hydroxyl groups of PET. Lastly, the esterification reaction is reversible at high temperature [10,11]. The objective of this study was to investigate the influence of rHDPE-rich blend composition on the mechanical properties.

Materials and Methods

The polymers investigated are recycled HDPE (rHDPE) as the major phase (matrix) and recycled PET (rPET) as the minor (dispersed) phase. The melt flow index and density of rHDPE were 0.072 g/10min at 190°C and 923 kg/m³, respectively. Ethylene glycidyl methacrylate (E-GMA), Lotader AX8840 with a melt index of 5g/10 min (190°C, 2.16 kg) and Lotader AX8900 with a melt index of 190°C/2.16 kg with a glycidyl methacrylate content of 8%, were used as compatibilizing agent. All the raw materials obtained from factory namely BioComposites Extrusion Sdn. Bhd.

The rHDPE and rPET weight ratios used were 80/20, 75/25, 70/30, 65/35, 60/40, 55/45 and 50/50 (wt/wt). The compatibilized rHDPE/rPET blends were prepared based on the 75/25 weight ratio of rHDPE and rPET into the blends.

Firstly, the formulated blends were tumble-mixed and melt-blended in a laboratory scale co-rotating twin screw extruder (Thermo Prism TSE 16 PC). The four barrel temperatures from the feeding to die zones were set as 250, 270, 240 and 190°C. The screw speed was 30 rpm. The extrudates were then cooled and granulated into pellets. The blend pellets were then compression molded at 200°C under 1000 psi by using a model LP50, LABTECH Engineering Company LTD. In the hot press process, the period of preheating, venting and full pressing was set to 3, 2 and 5 min, respectively. Following, cold press was set to 5 min to cool the specimen sheets.

Finally, composites plates were cut into the impact specimens according to ASTM standard D256-05. Izod impact test was done using Ray-Ran Universal Pendulum Impact System at room temperature. The Izod impact testing was carried out at velocity of 3.45 ms⁻¹, load weight of 0.452kg and calibration energy of 2.765 J. The infrared spectra in the FTIR-ATR of rPET, rHDPE, E-GMA and their blends were obtained using a FTIR-Near Infra Red with imaging system (Perkin Elmer Spectrum 400 FT-IR). The samples were analyzed over the range of 650-4000 cm⁻¹. This analysis of the blends was performed at point-to-point contact with a pressure device.

Results and Discussion.

Impact properties of the uncompatibilized blends were dependent upon blend ratio of HDPE and PET. The impact strength of the blends were decreased by adding rPET concentration as shown in Fig 1 (a). This was caused by the increased stress concentration and entanglements between the rPET fibres during the molding process [11]. This phenomenon was due to the improvement of reinforcing effect, allowing more even stress distribution from the rHDPE matrix to the rPET fibres and causes the blend stiffness to increase [12].

The compatibilized rHDPE/rPET blends with 7.5 % E-GMA using Lotader AX8840 exhibited a greater impact strength than Lotader AX8900 as shown in Fig 1 (b). The presence of a compatibilizer in the blend hinders the nucleation effect of rPET fibres, leading to a little thermal contraction; however, rHDPE undergoes crystallization and contracts strongly during cooling from the melt [13]. This results also indicates that the presence of compatibilizer leads to a significant improvement in the interfacial bonding, better dispersion and better bonding between the blends. Fig. 1(b) shows the relationship between compatibilizer ratio and it can be seen that the blend with compatibilizer impart higher modulus that other ratio especially using Lotader AX8840 as compatibilizer. As discussed earlier, this may be attributed to the improvement in the blends bonding, which leads to an increased in the efficiency of stress transfer inter phases.

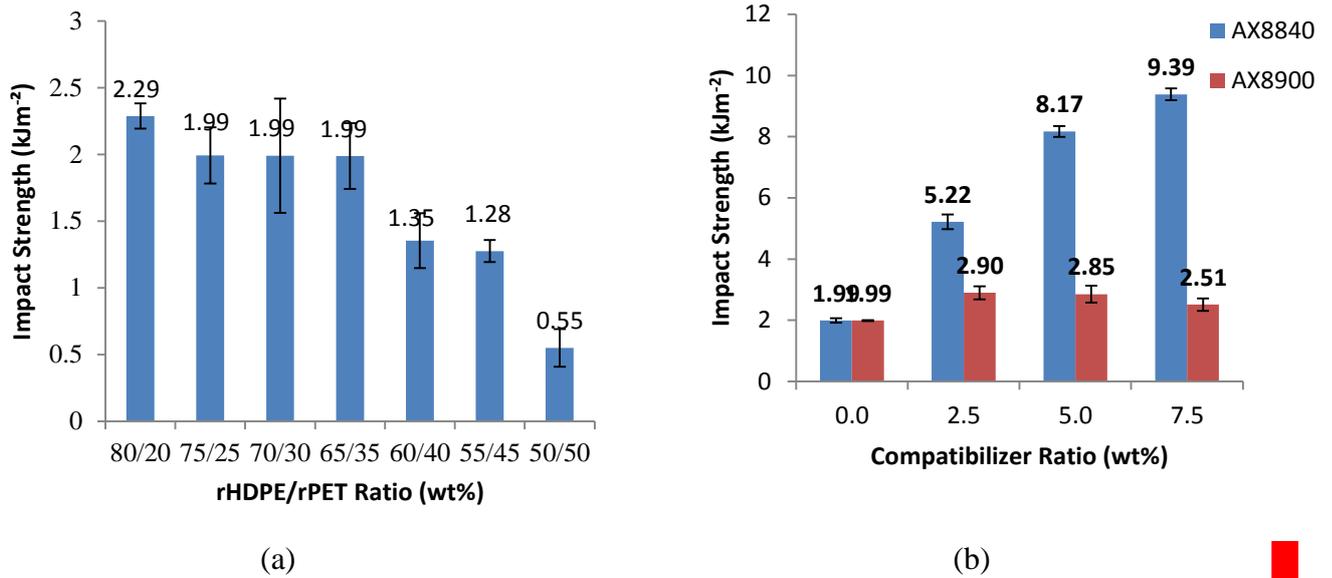


Figure 1. (a) Impact strength of uncompatibilized rHDPE / rPET blends as a function of rPET composition. (b) Effect of compatibilizer loading on impact strength

Figure 2 illustrate FTIR spectra of uncompatibilized and compatibilized rHDPE/rPET blends with 5% E-GMA (Lotader AX8840 and AX8900). The C=O stretching of the ester group in E-GMA and rPET was seen by the appearance of absorption band at 1734 cm^{-1} and 1713 cm^{-1} , respectively. E-GMA had three peaks of weak absorption intensity at about 997 cm^{-1} , 912 cm^{-1} and 846 cm^{-1} , corresponding to the characteristic IR signal of glycidyl epoxy group. Figure 2 also shows the peaks of 997 cm^{-1} and 912 cm^{-1} were disappeared for rHDPE/rPET/E-GMA ternary blend. Since E-GMA remained unaltered during melt-blending by extrusion, the absence of 997 cm^{-1} and 912 cm^{-1} absorption band was evidence for epoxy ring-opening reactions with the $-\text{OH}$ and $-\text{COOH}$ terminal groups of rPET [8]

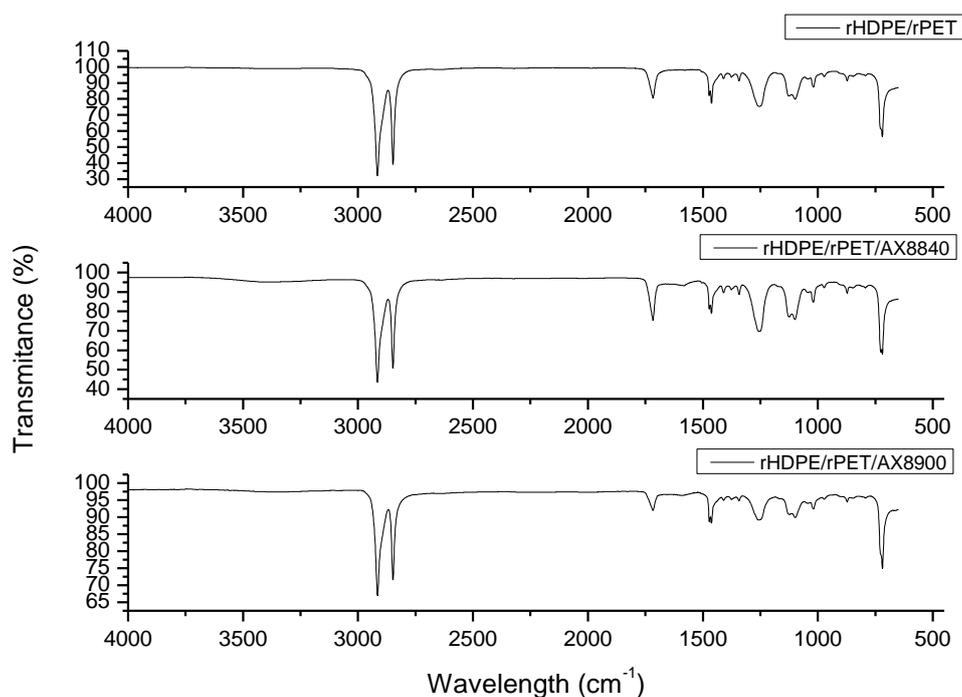


Figure 2. FTIR spectra of uncompatibilized and compatibilized rHDPE/rPET blends with 5 php Lotader AX8840 and Lotader AX8900.

Conclusions

A series of rHDPE/rPET binary and rHDPE/rPET/E-GMA ternary blends was prepared via melt blending for the investigation of impact and chemical stability. In blends without compatibilizer, the more rPET concentration in blend resulted in weaker distribution of dispersed phase. The application of E-GMA was proven to be effective in increasing the interactions between two phases progressively and enhancing the phase dispersion of the blends. This was confirmed by the FTIR results that demonstrate the esterification reaction between the both functionality of GMA and rPET.

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