Valorisation of waste polyethylene by blending with ethylene-vinyl acetate and incorporation of a new type of compatibilizer

Simon-Stőger L.[1,*], Varga Cs.[1]

[1]Institutional Department of MOL Hydrocarbon and Coal Processing, University of Pannonia, Veszprém 8200, Hungary

*corresponding author: e-mail: slilla@almos.uni-pannon.hu

Abstract

Nowadays polyethylene is one of the polymers produced in the greatest volume, therefore, parallelly the amount of generated waste polyethylene (w-HDPE) significant as well. Valorisation and recycling of w-HDPE can be realized by blending with different types of polymers and/or elastomers in order to result in thermoplastic elastomer end-product for example. One potential candidate can be ethylene-vinyl acetate (EVA) nevertheless interfacial interaction between w-HDPE and EVA is inadequate reflected in deterioration of mechanical properties of the blend in spite of the fact that they possess favourable mechanical properties themselves and they may complement each other. For the purpose of boosting of interfacial interactions between these two polymers experimental olefin-maleic-anhydride based additives have been incorporated in the blends after optimization of the processing temperature. Impact and tensile tests have been carried out in our research work besides microscopy measurements and investigation of the effects of additive structure by FT-IR and rheology.

Keywords: polymer blend, waste management, mechanical tests, interfacial interaction, valorisation

1. Introduction

Relatively high performance and low cost are provided by PE/EVA blends, furthermore a product with a desirable end-use characteristics can be reached by them. Toughness, transparency, environmental stress cracking resistance, flexibility, thermal resistivity, electrical resistance and the capability of filler carrying might be improved by addition of EVA into PE (Faker et al., 2008). Therefore it is used in many applications like high voltage cable system, automobile parts, agricultural films, multilayer packaging films and sheets. Formation of covalent bonds between PE and EVA are hindered by their structural differences and the isolated phases reveal as a barrier limiting effective stress transfer leading to deteriorated mechanical properties of the blend (Hamim et al., 2016). Stabilization of the morphology and formation of a proper interphase can be created by incorporation of some compatibilizer into the blend which act as a dispersant that decrease characteristic size of the heterogeneous morphology and boosts interfacial interaction between the continuous and dispersed phase. Processing temperature has also a significant effect on the adhesion between the phases of the blend. 180 °C is the minimal temperature suggested for processing which caused improvement in the mechanical properties. Some research works have focused on the blending and compatibilizing of PE and EVA, but only infinitesimal work have been prepared based on waste sources. Main aim of our study has been achieving balance between the maximization of waste content and increasing of the mechanical properties in the blend parallelly by addition of experimental compatibilizers.

2. Experimental

2.1. Materials

w-HDPE originated from the caps of polyethylene terephthalate (PET) bottles collected in different colours. The ratio of the collected caps was kept at a fixed value and melt flow index (MFI) of that mixed polyethylene pellet was of 5.3 g/10 min (230 °C, 2.16 kg). EVA copolymer IBUCELL K100 (H.B. Fuller) possessed VA content of 28 %. Experimental olefin-maleic-anhydride copolymer based additives (AD-1, AD-2) (Figure 1.) possessed four different types of functional groups (anhydride, half-ester, ester-amide and imide) and their polar behaviour could be controlled by changing their ratio to each other (Simon-Stőger et al., 2019).

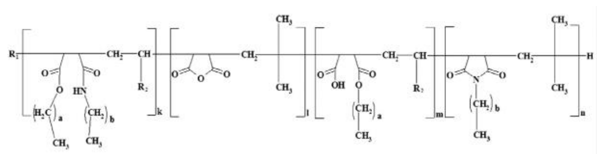

Figure 1. Structure of experimental olefin-maleic-anhydride copolymer based additives

(R_1: alkyl group with length of the olefinic monomer with R_1-2 carbon number; a: 3-40; b: 3-32; k: 0.2-2; l: 1-7; m: 1-7 and n: 0.3-2)

A commercial maleated PE (Polybond 3009–PB) has been applied as a reference having a typical maleic anhydride content in the range of 0.8 to 1.2 %, density of 0.95 g/cm^3 and melt temperature of 127 °C.

2.2. Sample preparation

Blends were prepared by a two-roll mill (LabTech Engineering Ltd., LRM-100) at two temperature combinations (140 °C – 180 °C; 180 °C – 220 °C).

After compression moulding the specimens were cut from the sheets with dimensions of 10 mm x 2.4 mm x 170 mm.

2.3. Measurements

Charpy impact strength at two temperatures and tensile properties of the blends were determined by an impact tester (CEAST Resil Impactor 6967.000) and an INSTRON 3345 single column universal tensile testing machine, respectively. Data were average of five parallel measurements. Tensile fracture surfaces of the blends were studied by SEM (Apreo, Thermo Fisher Scientific). Chemical structures of the experimental compatibilizers were determined by an FTIR spectrometer (Bruker, USA). Rheological tests of the experimental additives were carried out by a dynamic shear rheometer (MCR 201, Anton Paar).

3. Results

Among the results of mechanical tests the elongation at break (EB) can be highlighted. Effects of the compatibilizers in concentration of 0.2 wt % on the EB in 70/30 w-HDPE/EVA blend is shown in the Figure 2. at two different processing temperatures. EB enhanced by 182 % with experimental additive AD-2, so that can be characterized as a thermoplastic elastomer.

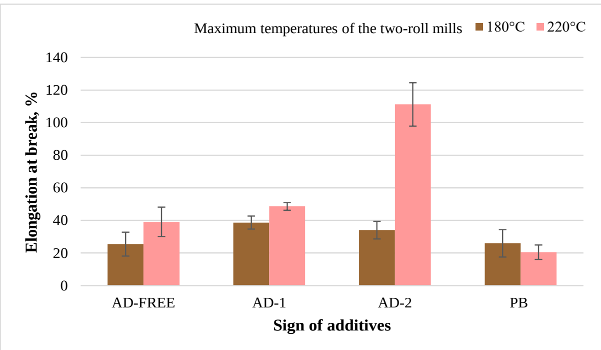

Figure 2. Elongation at break of 70/30 w-HDPE/EVA

Incorporation of AD-2 into the blend improved interfacial interaction between the polymer phases and the interlocking of them revealed in high elasticity. AD-2 can be characterized by a longer copolymer chain, predominant presence of nitrogen containing groups (ester-amide and imide) and only a few percent of anhydride group. Nevertheless softening effect of AD-2 could be experienced in the other tensile properties like slightly decrement in tensile strength and tensile modulus. Elasticity is confirmed by Figure 3. which clearly shows the structured fibers on tensile fracture surface of the blend referring to the uniformity and homogeneity compared to the uncompatibilized one. It is important to note that EVA is able to influence the crystallinity of the blend since increasing vinyl acetate content resulted in decreased crystallinity by obstruction, in increased mobility of polymer chains supported by orientation, and in decreasing tensile strength.

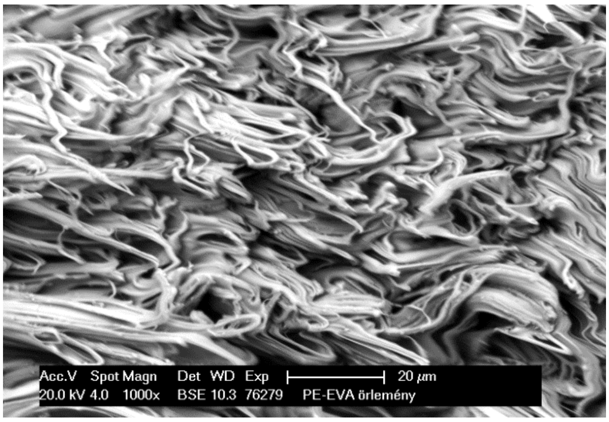

Figure 3. SEM micrograph of w-HDPE/EVA 70/30 compatibilized by AD-2 and processed at 220 °C

FT-IR spectra of the additives (Figure 4.) had the typical stretching vibrations for carbonyl functional groups originated from different chemical environment.

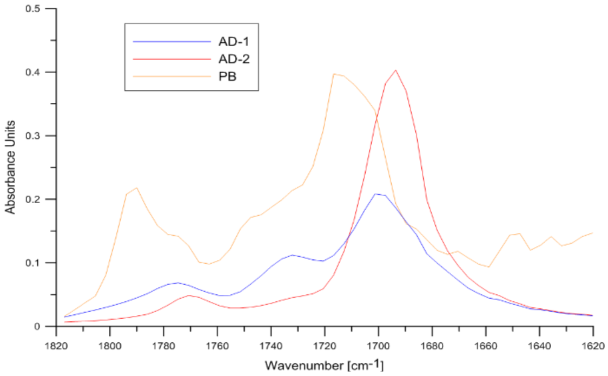

Figure 4. FT-IR spectra of the compatibilizers between wavenumber of 1820 cm^{-1} and 1620 cm^{-1}

4. Conclusion

Incorporation of experimental compatibilizers were able to enhance impact strength and EB of the blends by boosting of interfacial interaction between the phases. The experimental "product" can be widely applied due to incorporation of some property specific compatibilizers for w-HDPE/EVA. Furthermore one of the most basic notions of sustainability, the 4R's (reduce, recycle, reuse, recover) could be also satisfied in a successful way.

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