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Research article

Compatibilization of HIPS/ABS blends from WEEE by using Styrene-Butadiene Rubber (SBR)

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ABSTRACT

The aim of this work is to develop compatibilization strategies for High Impact Polystyrene (HIPS)/Acrylonitrile-Butadiene-Styrene (ABS) blends from WEEE in order to add value to these recycled plastics by improving their mechanical performance. Results from a screening study of HIPS/ABS blends compatibilization by the addition of Styrene-Butadiene Rubber (SBR) are presented. Two different weight proportion of HIPS/ABS physical blends were analyzed, 80/20 and 20/80, with three different concentration of SBR: 2, 10 and 20 wt%. Compatibilization efficiency was analyzed from an accurate thermal and mechanical analysis, by comparing each physical blend and corresponding compatibilized blends with SBR. Results were discussed relating glass transition changes with mechanical performance, both aspects were interpreted in terms of blend morphology. Phase and fillers dispersion and distribution as well as SBR amount and its interaction with each phase were accurate analyzed.

Compatibilization of HIPS/ABS blends from WEEE with the addition of SBR is effective in blends with HIPS as main component. With the addition of 2 wt% of SBR, strength and toughness have notably increased respect to the corresponding physical blend, 244% and 186% respectively. From this screening study is possible to infer that SBR is a sustainable and efficient compatibilizer of HIPS rich blends allowing to obtain a final blend that can be used as a replacement material of separated resins from WEEE.

1. Introduction

Waste from Electrical and Electronic Equipment (WEEE) is a waste stream which grows continuous and exponentially fast, mainly because the increase of high technology and short useful life products consumption (European Union, 2012; Namias, 2013). WEEE management is complex as this stream includes several kinds of materials. It contains both, elements of high intrinsic value that can be recovered with economic benefits (precious metals, glass, plastics, etc) and hazardous substances like mercury, bromine, heavy metals, among others (Baldé et al., 2015). Within WEEE, plastics are not considered the most relevant material because they are not highly dangerous and their cost are relatively low against precious metals like gold. However, they occupy lot of space in final disposal because of their low density, shape, low compressibility and resilience. Around 18 wt% of WEEE are plastics, generally thermoplastic then they can be easy recycled by reprocessing (Baxter et al., 2014, 2016; Chagnes et al., 2016). In addition, statistical reports predict that worldwide amount of WEEE generated in 2016 was about 46 million tons (Mt). It means that 8.5 Mt of plastic WEEE were produced in that year expecting to reach up 9.5 Mt in 2018 (Baldé et al., 2015; Magalini et al., 2015; Zeng et al., 2017).

In order to diminish the disposal of WEEE as hazardous material, different kind of regulations are being implemented in several parts of the world (Stevels et al., 2013). They promote separation and special disposal for toxic and dangerous components of WEEE. With the rest, regulations mainly incentive reuse and recycling first to final disposal. In the European Union (EU) there are specific directives for WEEE management which involves responsibilities from the producer to final consumer. Their purpose is to prevent further increasing in WEEE, promote different types of recovery and enhance environmental treatment of all areas involved in WEEE generation (European Union, 2012; Ongondo et al., 2011). Also, directives regulate concentration ranges of bromine in plastic

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WEEE as well as, other hazardous materials in order to promote safe WEEE management in all steps, including recycling (European Union, 2011). Particularly in USA, IEEE Standard 1608 recommends to manufacturing industries of electrical and electronic devices housings to use at least 25 wt% of certified post-consumer material (IEEE Standard, 2006). This standard enhances the incoming of plastic WEEE to main manufacturer locations like China, Vietnam or Taiwan from the rest of the world, mainly third world countries (Namias, 2013). Usually, plastic WEEE are exported chopped and separated by type but, their sorting by type using automatic methods is very difficult as their composition is similar (Beigbeder et al., 2013; Campolina et al., 2017; Maris et al., 2015). In this way, manual sorting is the most popular method although it involves higher labor costs and unsafe and unhealthy labor conditions for workers (Ceballos et al., 2014). It is important to note that complete manual separation cannot be guaranteed since is typically made by color and source and, eventually separated resins could contain others plastics (Bernardeau et al., 2018). Consequently, the added value of recycled resins and recycler's profits decrease.

An alternative for diminishing the above problems and to increment added value of plastics from WEEE is avoid sorting by type and recycling them together by melt blending. However, it is well known that direct blending of two or more thermoplastic resins in appreciable proportions causes phase segregation, low interfacial adhesion and consequently mechanical properties deterioration. Then, an adequate compatibilization process is essential to increases phase adhesion, reduces the interfacial tension, stabilizes morphology by inhibiting droplet coalescence and consequently, improves mechanical properties (Davis et al., 2000; Elmendorp et al., 1991; Utracki, 1991; Wu, 1982). Main compatibilization methodologies involve a third component as a compatibilizer. In one of them, the compatibilizer is generated by a chemical reaction directly in the interphase during melt blending. This “in-situ compatibilization” is the most efficient because all the reactive generated acts as compatibilizer but it is not adequate for its use with recycled resins. The main reason proceeds from the possible variation in recycled resins composition and their additives that could affect chemical reaction efficiency. On the other hand, the most practical compatibilization methodology able for plastic recycling is the direct addition of a copolymer as compatibilizer during melt blending. This method involves the migration of the compatibilizer to the interphase. For this reason, compatibilizer molecules should contain similar segments to initial materials to better interact with them and then, improve load transfer and phase adhesion (Utracki, 2002). Please note that, despite it is less effective than in situ compatibilization, its efficiency is less affected by components composition and additives then it is not worker-dependent and friendly for them. In this sense, the challenge is to obtain materials with similar performance to recycled WEEE separated resins by blending them together with an adequate compatibilization strategy.

WEEE plastics are copolymers with complex morphologies which contain additives/mineral fillers like calcium and magnesium carbonate, silica, brominated substances, carbon black, among others. Then, they are composite materials which contain a very complex copolymer blend as matrix, multiple minerals as fillers and several additives (Arnold et al., 2009; Vazquez and Barbosa, 2016). The major fraction of plastic WEEE stream (71 wt%) is composed by ABS (Acrylonitrile-Butadiene-Styrene), HIPS (High Impact Poly-Styrene), and Polypropylene (PP), while Polycarbonate (PC), Polyamides (PA), Polymethylmethacrylate (PMMA), among others, represent the minor fraction (29 wt%). ABS and HIPS are two of the most common and abundant plastics in this waste stream, representing 29 wt% and 22 wt% of the total amount of plastics (Maris et al., 2015; Martinho et al., 2012). Their mechanical properties are highly dependent of Butadiene (Bu) phase and also both, HIPS and ABS, are themselves mixtures of several components and their morphology highly depends on relative compositions, additives/fillers amount, and phase segregations (Hirayama and Saron, 2018; Bisio and Xanthos, 1995).

Considering that, HIPS and ABS are the major components of plastic WEEE and they are the most difficult to separate because of their physicochemical similarity, the selected system for this study includes blends of these plastic resins from WEEE. In literature, there are some works that studied HIPS/ABS blends compatibilization mainly on virgin resins. Peydro Rasero et al. (2015) considered SEBS (Styrene-Ethylene-Butylene-Styrene) to improve ductility of virgin HIPS/ABS blends for having similar polymeric segments to them. Their results showed an increment in elongation at break with tensile strength decrement. Also, Arnold et al. claims that in HIPS/ABS blends from virgin and WEEE plastic resins, properties suffer a deterioration respect to the corresponding base materials and consequently, final blend has poor added value (Arnold et al., 2010). However, as it was demonstrated in a previous work, plastic WEEE far differs from their correspondent virgin resins because of the fillers and additives presence (Vazquez and Barbosa, 2016). Taking into account that both, fillers and additives influence final blend properties and compatibilizer effect, it is necessary to find specifics compatibilization methodologies for blends of HIPS/ABS from WEEE.

The aim of the present work is to develop compatibilization strategies for HIPS/ABS blends from WEEE in order to increase added value of these recycled plastics by improving their final mechanical performance. Styrene-Butadiene Rubber (SBR) was selected as compatibilizer for having similar molecular segments either to ABS or to HIPS, as well as for its low cost. In this sense, two different weight proportion of HIPS/ABS WEEE physical blends were selected, 80/20 and 20/80, and in order to perform a screening study three SBR concentration were used, one very low (2 wt%), one higher enough (20 wt%) and another one in the middle (10 wt%). The influence of SBR content for each relative HIPS/ABS WEEE proportion was analyzed. Results were discussed relating glass transition temperature changes with mechanical performance and, both were interpreted in terms of morphological aspects. Dispersion and distribution of polymeric phases and fillers as well as SBR interaction with each phase were also analyzed accurately.

2. Experimental

2.1. Materials

HIPS and ABS from e-scrap were used as initial materials of blends. They were kindly provided in powder form by Ecotécnica del Pilar S.R.L. Each plastic WEEE material sample used in this work were obtained by mixing 10 powder portions of 500 g from different places of a 25 kg commercial bag in order to have a representative sample of each initial plastic e-scrap. SBR ARPOL 1502 from Petrobras was used as compatibilizer of WEEE blends.

2.2. Blending

HIPS(80 wt%)/ABS(20 wt%) and HIPS(20 wt%)/ABS(80 wt%) physical blends from WEEE were prepared under nitrogen atmosphere, in a batch mixer (*Brabender Plastograph W50*) at 180 °C and 30 rpm for 10 min (Brennan et al., 2002; Utracki, 1991). From this point, HIPS and ABS mean HIPS WEEE and ABS WEEE. Each initial ABS and HIPS as well as compatibilized blends were processed in the same batch mixer under the same condition as physical one. In order to make a screening test, three different concentration of compatibilizer were chosen. In this way, 2, 10 and 20 wt% of SBR