Recycled Car Bumpers' Impact Resistance Investigated By Wide-Angle X-ray Diffraction

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ABSTRACT: The recycled polyolefinic product from discarded standard car bumpers collected from Rio de Janeiro suburb shops was characterized by mechanical and wide-angle X-ray scattering (WAXS) methods. We found that the recycled plastic mixture is composed mainly of polypropylene (PP), containing ethylene-propylene-diene (EPDM) terpolymers and a minor proportion of high-density polyethylene (HDPE), and is highly resistant to impact. The results were compared with the corresponding data obtained from binary and ternary blends of virgin PP, EPDM, and HDPE. © 2000 John Wiley & Sons, Inc. J Appl Polym Sci 75: 999–1004, 2000

Key words: recycled plastic; discarded car bumpers; polyolefin identification by WAXS; PP/EPDM/HDPE blends

INTRODUCTION

The automobile industry uses a large diversity of materials, from metals to polymers, prepared as molded products made by a variety of processes in many different forms, as well as adhesives and paints. The main objective is to obtain a vehicle with improved aesthetic and comfort characteristics. There are also general requirements such as reduction in noise, vibration, weight, and material consumption, besides ecological requisites. Plastic materials are increasingly being used today in wide areas of applications, primarily owing to their versatility and advantages such as corrosion resistance, light weight, energy efficiency, and design flexibility.[1,2]

Among the plastic parts used in vehicles, polypropylene (PP) bumpers have relatively simple material compositions and because of their large size they have been targeted for recycling throughout the world. There is a tendency to increase the PP proportion in the molding compositions for the automotive industry; car markers are looking to improve recyclability of components by making them easy to disassemble and by reducing the number of different polymer families in a vehicle.[3–5]

Due to low cost, improved impact properties, and capability of recycling, thermoplastic polyolefin (TPO) compounds are expanding their usage in automotive applications. TPO compounds are physical blends of PP and elastomeric ethylene, propylene (EP) copolymers, or ethylene-propylene-diene (EPDM) terpolymers; they are of particular interest for car bumpers.[6–8]

In this present paper, the recycled material from used car bumpers was investigated by mechanical and X-ray scattering (WAXS) methods. The results were compared with the corresponding data obtained from binary and ternary blends of virgin polyolefins of similar composition to the recycled product.

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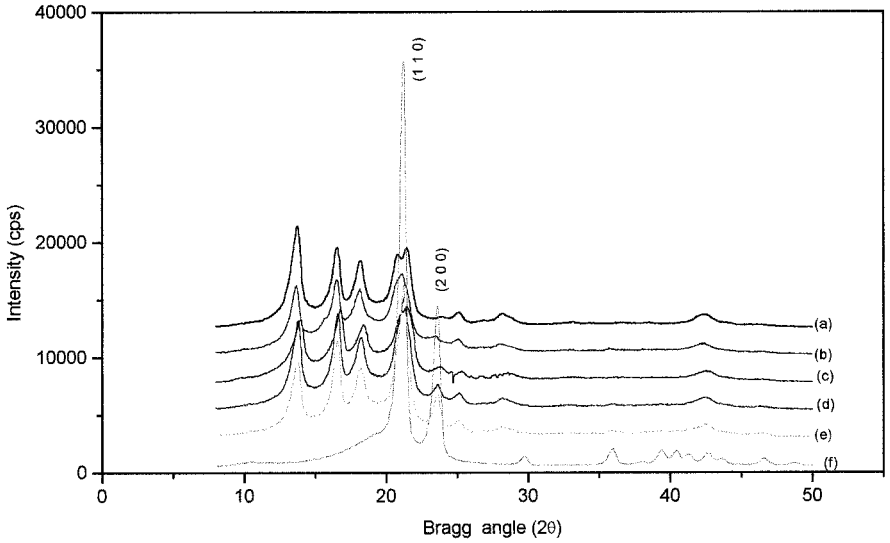


Figure 1 Virgin and recycled polyolefin WAXS patterns - 2θ scans from 8 to 60° at room temperature. (a) PP; (b) recycled material; (c) PP/HDPE/EPDM 85/5/10; (d) PP/HDPE/EPDM 80/10/10; (e) PP/HDPE/EPDM 70/20/10; (f) HDPE.

EXPERIMENTAL

Materials

1. Polypropylene (PP), supplied by OPP Petroquimica S.A., Brazil; type H301; specific gravity, 0.91; MFI, 10 g/10 min;
2. Ethylene-propylene-diene-methylene (EPDM), supplied by DSM Elastomeros Brasil Ltda, Brazil; type Keltan 57C; specific gravity, 0.86; Mooney viscosity, 61;
3. High-density polyethylene (HDPE), supplied by Polialden Petroquimica S.A., Brazil; type BT003; specific gravity, 0.94; MFI, 0.3 g/10 min;
4. Plastic waste from used auto bumpers from five different makers, supplied by Gerauto Ltda, Brazil.

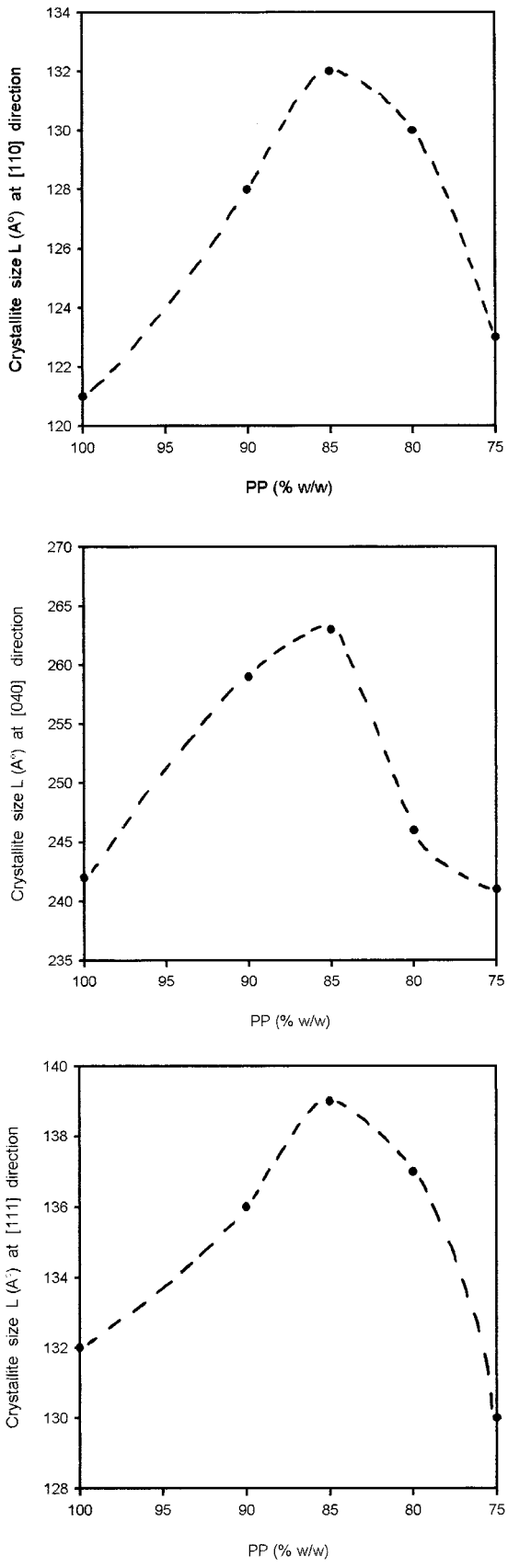
Methods

Plastic waste material from used bumpers (about 60 kg) was submitted to cutting, washing with water, drying and grinding, resulting small fragments (under 2.0 cm larger dimension). A representative sample was taken according to ABNT NBR 10007 method.[9] The fragments were separated by floating successively in water and ethanol solutions (specific gravity, 0.94 and 0.91, respectively) in 150-L tanks. The fractions were dried over newspaper sheets on the floor at room temperature (30°C).[10] The polyolefins compounds were prepared in a Haake Rheocord 9000 equipment with a Rheomix 600 roller rotor mixer, at 60 rpm. The processing time and temperature were chosen according to the material. The compositions were 90/10, 85/15, 80/20, and 75/25 for PP/EPDM binary blends, and 85/5/10, 80/10/10, and 70/20/10 for PP/HDPE/EPDM ternary blends. All mixtures were processed at 180°C for 5 min.

WAXS measurements were carried out in a standard Seifert-FPM GmbH diffractometer, operating with CuKα (λ= 1.5418Å) radiations in 40 kV and 30 mA, equipped with a graphite monochromator in the primary beam, using symmetrical transmission method with 2θ scans in steps of 0.05°. Crystallite size for polymer samples was calculated according to the Hosemann model,[11] considering long-range paracrystalline disorder factors present in crystalline domains. Specific gravity measurements were taken according to ASTM D792. Izod impact tests were carried out in a Testing Machines Inc. impact tester, model TMI 43-1, 614/04C grooves according to ASTM D256. Samples were cut from 0.6 × 15.0 × 15.0 cm plates, molded in a Carver press at 188°C and 22.2 kN, for 5 min.

RESULTS AND DISCUSSION

Pretreatment of the plastic waste from used bumpers by industrial grinding resulted in 5%



loss in weight. Most of this material was separated by floating in water, indicating polyolefins. There was no separation in 0.94 and 0.91 ethanol solutions. The only fraction obtained had specific gravity under 0.91. These results indicated that the discarded bumpers were mostly composed of PP.

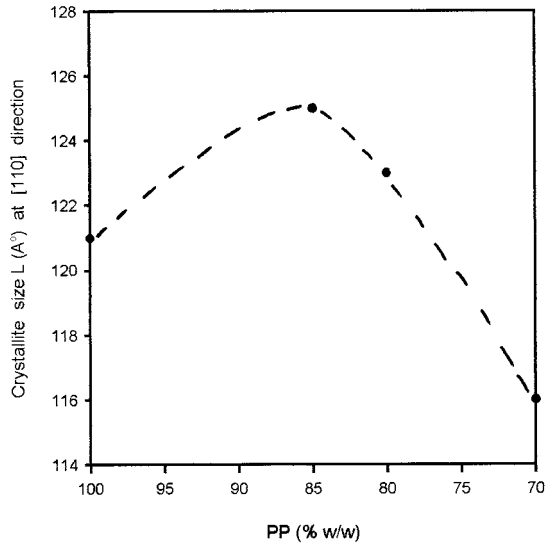
Differential scanning calorimetry (DSC) analyses confirmed that the compositions of discarded bumpers contained a large predominance of PP, as expected. The recycled material showed also a T_m peak at 127°C, which could be attributed to HDPE (T_m: 135°C). The presence of EPDM was confirmed by NMR analyses.[10,12] Due to HDPE high crystallinity, its presence and proportion, even in small quantities, could be determined by WAXS measurements, comparing with binary and ternary virgin polyolefin blends.

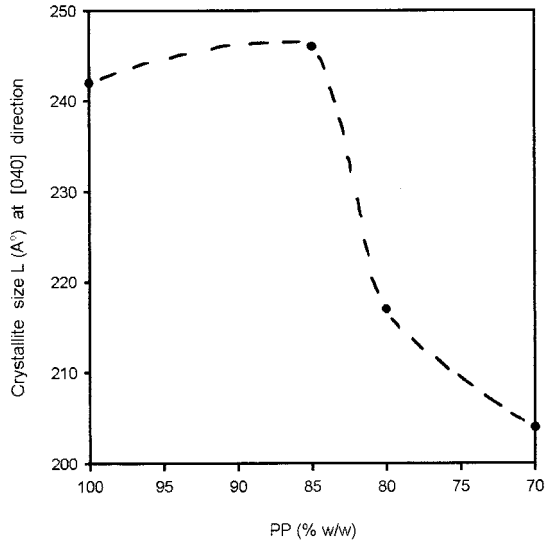
WAXS patterns of PP, HDPE, recycled material, and virgin PP/HDPE/EPDM ternary blends are seen in Figure 1. Typical PP reflections are shown in the recycled material diffractograms, as well as very small reflections due to (110) and (200) HDPE planes. These results confirmed the presence of HDPE in small amount in the discarded bumpers composition. Being an amorphous polymer, EPDM does not show any reflection by WAXS.

Figure 2 shows the PP crystallite size at [110], [040], and [111] directions for virgin PP/EPDM binary blends. It is interesting to observe that there was an increase of PP crystallite size in blends containing up to 15% EPDM. The presence of EPDM seems to favor the crystallization of PP in the b direction over the a and c directions. These results suggest that the incorporation of up to 15% of EPDM to PP mixtures provoked the PP domains segregation because of the incompatibility of the ethylene and propylene sequences. Because ethylene is the predominant chemical unit in EPDM, it may have favored the organization of the PP disordered regions.

The PP crystallite size in virgin PP/HDPE/EPDM ternary blends is shown in Figure 3. It is interesting to register that PP showed the same behavior revealed in binary blends for crystallization of the unit cell. Figure 4 presents the corresponding data for HDPE crystallite size in

Figure 2 PP crystallite size in different directions for virgin PP/EPDM binary blends. (a) [110]; (b) [040]; (c) [111].





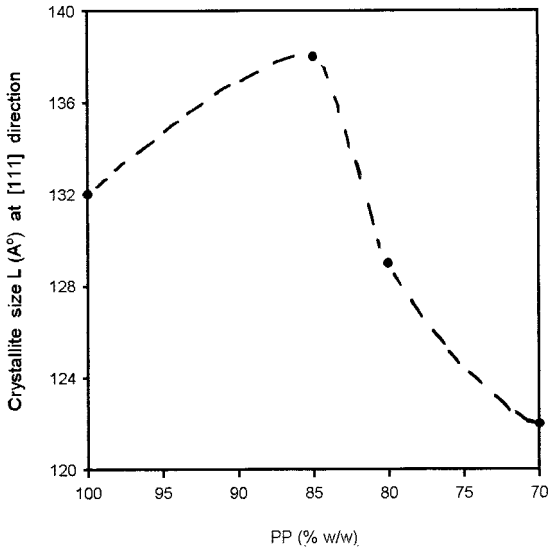
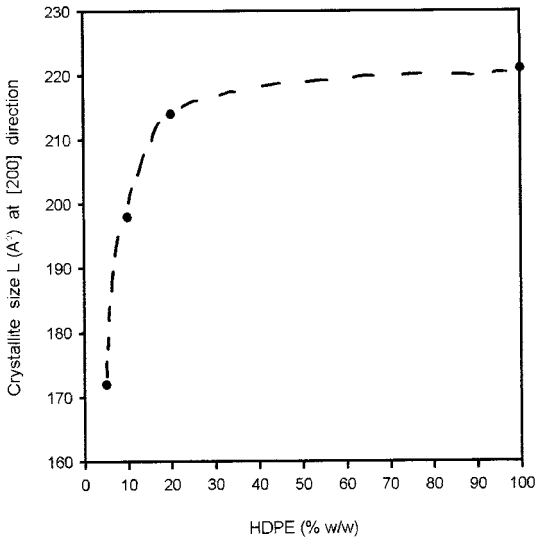
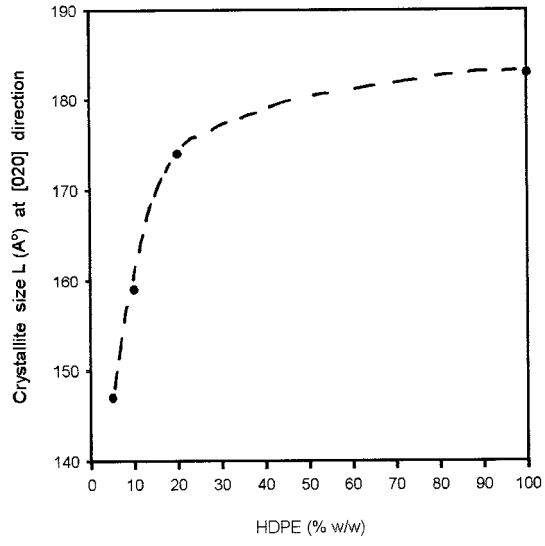


Figure 3 PP crystallite size in different directions for virgin PP/HDPE/EPDM ternary blends. (a) [110]; (b) [040]; (c) [111].





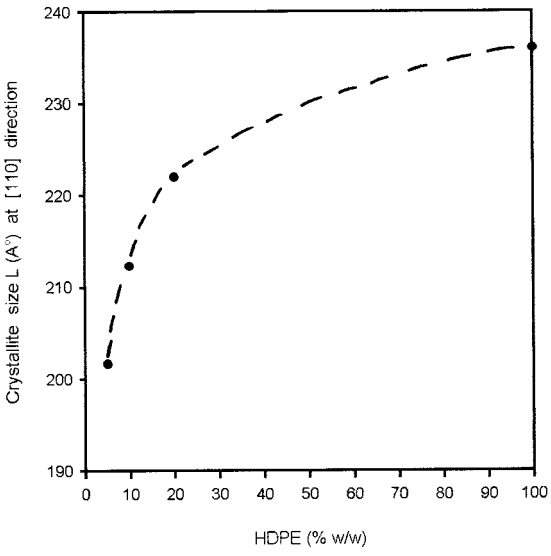


Figure 4 HDPE crystallite size in different directions for virgin PP/HDPE/EPDM ternary blends. (a) [200]; (b) [020]; (c) [110].

those mixtures at [200], [020], and [110] directions. The increase in the HDPE content caused the enlargement of its crystallites in all directions. These results could be expected because of the affinity of EPDM to HDPE, which could facilitate HDPE crystallization.

Figure 5 shows PP lattice $\underline{a}$ parameter in virgin PP/HDPE/ EPDM ternary blends. This parameter increased up to 85% PP content in the mixtures and decreased onwards. Higher values for this parameter indicate low crystalline organization. In the case of car bumpers, a crystalline polymeric mass is not adequate because of its brittleness. So, higher $\underline{a}$ values are preferable for car bumpers. For the recycled bumpers, the lattice parameter $\underline{a}$ was 6.72. This corresponds to an HDPE content under 5% in the recycled material. Higher percentages of HDPE would lead to higher crystallization (Fig. 4), which is undesirable for car bumpers. The results we found are in agreement with an adequate composition for the car bumpers.

The impact resistance of polyolefins under investigation is presented in Table I. As expected, the addition of EPDM increased the impact resistance of PP in the PP/EPDM binary mixtures containing up to 25% EPDM. The addition of 5% of HDPE on 85/10 PP/EPDM binary blend caused an expressive increase on its impact resistance, which is an important requirement for car bumpers. PP/HDPE/EPDM ternary blends are as good as PP/EPDM binary blends as far as impact resistance is concerned. The choice will depend mostly on the raw materials cost.

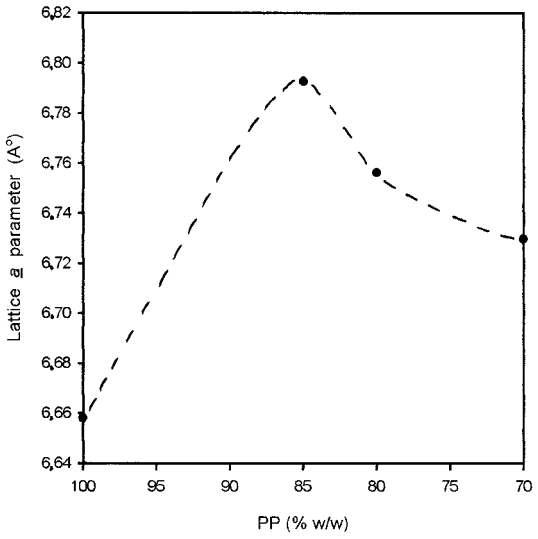


Figure 5 PP lattice $\underline{a}$ parameter in virgin PP/HDPE/ EPDM ternary blends.

Table I Impact Resistance of Polyolefins

PP/HDPE/EPDM Blends (p/p/p)	Impact Resistance (J/m)
100/0/0	9
90/0/10	17
85/0/15	21
80/0/20	33
75/0/25	37
85/5/10	37
80/10/10	25
70/20/10	26
Recycled Material	260

It is important to register the much higher value of the impact resistance of the recycled material, 260 J/m. It is ten times higher than the values obtained for virgin binary and ternary polyolefin blends. This unexpected result may be explained by the crosslinking originated by the degradation of the carbon chains in the recycled material, associated to better dispersion of elastomeric domains in the PP matrix due to interfacial compatibilization of the components. This recycled material may be an useful material for several applications in the automotive industry.

CONCLUSIONS

Recycled plastics recovered from discarded car bumpers are highly resistant to impact and consist of a ternary mixture composed mainly of PP, containing also EPDM and a minor proportion of HDPE. Those PP/HDPE/EPDM ternary blends are as good as PP/EPDM binary blends as far as impact resistance is concerned. The choice will depend mostly on the raw materials cost. The recycled product is an useful material for several applications.

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