AIP Conference Proceedings

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Citation: AIP Conference Proceedings **1593**, 658 (2014); doi: 10.1063/1.4873865
View online: http://dx.doi.org/10.1063/1.4873865
View Table of Contents: http://scitation.aip.org/content/aip/proceeding/aipcp/1593?ver=pdfcov
Published by the AIP Publishing

Recycling Cycle of Materials Applied to Acrylonitrile-Butadiene-Styrene/Policarbonate Blends with Styrene-Butadiene-Styrene Copolymer Addition

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Abstract

The scope of this research is the recycling of polymers from mobile phones hulls discarded and the performance evaluation when they are submitted to the Recycling Cycle of Materials (RCM). The studied material was the ABS/PC blend in a 70/30 proportion. Different compositions were evaluated adding virgin material, recycled material and using the copolymer SBS as impact modifier. In order to evaluate the properties of material's composition, the samples were characterized by TGA, FTIR, SEM, IZOD impact strength and tensile strength tests. At the first stage, the presented results suggest the composition containing 25% of recycled material and 5% of SBS combines good mechanical performance to the higher content of recycled material and lower content of impact modifier providing major benefits to recycling plans. Five cycles (RCM) were applied in the second stage; they evidenced a decrease trend considering the impact strength. At first and second cycle the impact strength was higher than reference material (ABS/PC blend) and from the fourth cycle it was lower. The superiority impact strength in the first and second cycles can be attributed to impact modifier effect. The thermal tests and the spectrometry didn't show the presence of degradation process in the material and the TGA curves demonstrated the process stability. The impact surface of each sample was observed at SEM. The microstructures are not homogeneous presenting voids and lamellar appearance, although the outer surface presents no defects, demonstrating good moldability. The present work aims to assess the life cycle of the material from the successive recycling processes.

Keywords: Recycling, Cycle, Materials, Processes.

INTRODUCTION

Replacing and disposing of mobile phone, computers and electronic equipments it is a fact increasingly common for consumers. Plastics are the main material which constitutes mobile phones. They are used in housing, key pad, many components and connector, representing about 43% of total weight [1]. The acrilonitrile-butadiene-styrene/polycarbonate blends (ABS/PC) are widely used in electronic equipments due their unique characteristics, such as high heat resistance, mechanical strength, rigidity, chemical stability and flame [2]. The ABS and PC polymers have high recyclability potential [3].

According Cândido [4], it is possible to recycle ABS/PC blends in multiple cycles by adding a part of virgin material in the first recycling cycle. The strength impact decreases gradually up to get the reference values of ABS/PC blend, composed by virgin material. Thus, when the blend properties are known by application of the Recycling Cycle of Materials (RCM) it is possible to evaluate more effectively the life cycle of materials. This review aims to guide the Product Design areas and Engineering Project concerning the recycling strategies for this blend.

In this sense, the main goal of this research is to identify the feasibility of recycling mobile phone case using the RCM model. At the first stage, some compositions were tested. They are composed by a fixed proportion of ABS/PC virgin material (70%) and a variable content of ABS/PC from mobile phone case, using the copolymer styrene-butadiene-styrene (SBS) as impact modifier. Tasdemir has studied the effect of SBS (1%, 5% e 10%) as compatibilizer to ABS/PC blends and he concluded that higher content of SBS provides greater elongation and impact strength but lower tensile strength and modulus of elasticity [5].

The presented results suggested a composition which combines good mechanical performance to the higher content of recycled material and lower content of impact modifier. This composition was submitted to RCM at the second stage.

EXPERIMENTAL

Materials

The materials used in this study are described bellow: the copolymer acrylonitrile-butadiene-styrene (ABS - Terluran GP-22) and the copolymer styrene-butadiene-styrene (SBS – Styroflex 2G 66), both supplied by BASF; the polycarbonate (PC-VR-2000) supplied by

Proceedings of PPS-29
AIP Conf. Proc. 1593, 658-661 (2014); doi: 10.1063/1.4873865
2014 AIP Publishing LLC 978-0-7354-1227-9/$30.00

Policarbonatos do Brasil and ABS/PC recycled from 230 mobile phone hulls discarded.

Injection Process Parameters

The specimens for the tensile strength and impact strength were obtained by the injection molding process, using a Battenfeld Plus 350. The mold temperature was kept at 80ºC and three temperature heating zones at 230ºC were used. The total time of process was 47 seconds.

Characterization

Tensile tests were performed according ASTM D 638, specimen type 1, in a Universal Tensile Machine INSTRON 3369, cell load of 50kN at a crosshead speed 50 mm/min. The Izod Impact tests were carried out at 23°C using a pendulum-type impact tester (Ceast, Resilimpact), according to ASTM D 256. The thermal stability was measured using thermo gravimetric analyzer PerkinElmer TGA 4000. The samples were heated from 23 to 800°C at the rate 10°C/min under an inert atmosphere of nitrogen. The FTIR spectrum was obtained in a PerkinElmer Spectrum 100, with resolution of 4cm^{-1} and 16 scans in a region between 4000 e 400 cm^{-1}. The microstructure was analyzed on the central region of fracture surface from IZOD samples by Scanning Electronic Microscopy - SEM equipment Hitachi TM-3000, with 15kv energy.

Methods

The methodology was applied in two stages. At first stage, seven different compositions were formulated according shown in Table 1. The compositions are denominated groups G1, G2, G3, G4, G% and G7.

TABLE 1 – Composition of ABS/PC/SBS/Recycled Material Blends

<table>
<tr><th>Group</th><th>ABS (%)</th><th>PC (%)</th><th>ABS/PC recycled (%)</th><th>SBS (%)</th></tr>
<tr><td>G1*</td><td>70</td><td>30</td><td>-</td><td>-</td></tr>
<tr><td>G2*</td><td>-</td><td>-</td><td>100</td><td>-</td></tr>
<tr><td>G3</td><td colspan="2" rowspan="5">70 % of 70ABS/30PC</td><td>30</td><td>0</td></tr>
<tr><td>G4</td><td>27,5</td><td>2,5</td></tr>
<tr><td>G5</td><td>25</td><td>5</td></tr>
<tr><td>G6</td><td>20</td><td>10</td></tr>
<tr><td>G7</td><td>15</td><td>15</td></tr>
</table>

* Reference groups.

The G1 group is the reference composition composed by virgin material. The G2 group was used to demonstrate the features of post-consumer material when it is recycled. The samples were characterized and one composition group was chosen to the second stage. The RCM is applied at second stage by reprocessing the material from chosen group. Five RCM were performed and samples were taken every cycle in order to characterize them. When the impact strength values were lower than reference material, it was added virgin material in the same proportion as the initial composition of the chosen group. Remaining samples from each cycle were submitted to the following cycle of recycling and reprocessing.

RESULTS AND DISCUSSION

First Stage

The FTIR results show there is no changes in peaks of the spectra in the G1 group to G7 group. In this case, the presence of some spectra just confirms the blend composition. In compositions with SBS content occurs overlapping peaks in ABS and SBS spectra's because they have similar composition concerning to the styrene and butadiene.

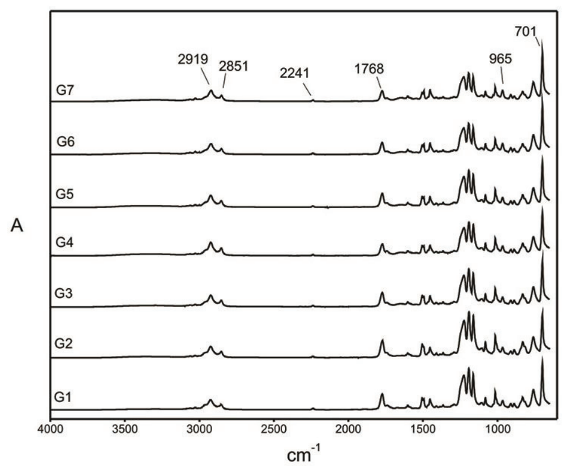

FIGURE 1 – FTIR spectra to composition groups.

The characteristic of mass loss temperatures are summarized in Figure 2 and Table 2.

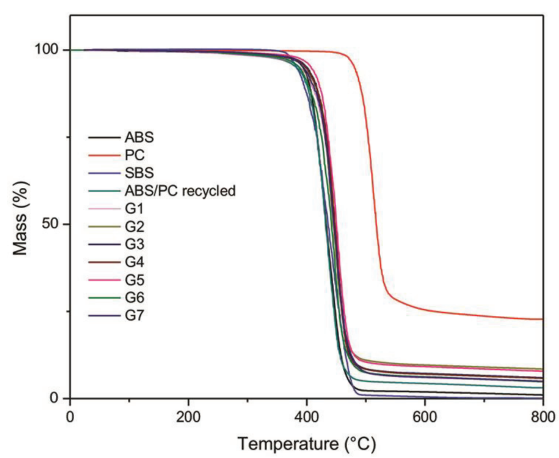

FIGURE 2 – TGA curves to composition groups.

The analysis of curves for ABS and PC blends shows that the degradation curves are far from that of pure PC, but are similar to those of pure ABS. Some interactions between both polymers during thermal degradation have to be considered, in particular the influence of ABS on thermal degradation of PC even with additions of small amounts of ABS [6].

TABLE 2 – TGA results to composition groups.

Composition Group	$T_{10\%}{}^{a}$(°C)	$T_{50\%}{}^{a}$(°C)
ABS	404	433
PC	492	521
SBS	394	433
ABS/PC recycled	399	430
G1	400	433
G2	401	431
G3	402	433
G4	401	433
G5	407	437
G6	393	428
G7	398	432

$T_{10\%}$ – temperature at which 10% of weight loss occurs.
$T_{50\%}$ – temperature at which 50% of weight loss occurs.
[a] Standard deviation ± 1 °C.

The influence of mechanical properties concerning Young Modulus and IZOD impact strength in every group from G1 to G7 is shown in Fig. 3.

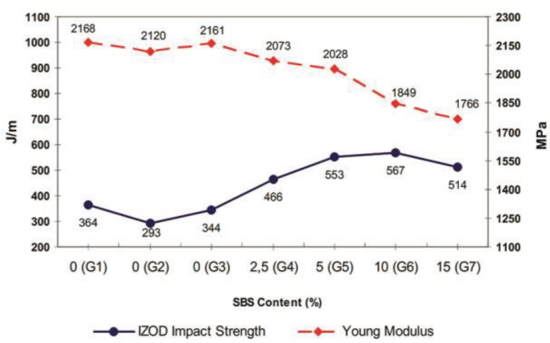

FIGURE 3 – Mechanical properties to composition groups.

The groups that do not contain SBS have higher modulus of elasticity, including G2 composed only by ABS/PC recycled from mobile phone case. From G4 to G6, the impact strength increases markedly, while the modulus of elasticity decreases gradually. In G7, which contains 15% of SBS, the impact strength begins to decrease. These results confirm that SBS in small amounts is effective as impact modifier in ABS/PC blends. These results confirm that small amounts of SBS are efficient as impact modifier in ABS/PC blends. The SBS content improves the impact strength and does not affect significantly the modulus of elasticity. The morphology from impact surface was observed at SEM. In Fig. 4 is possible to verify that groups composed only by ABS/PC (G1 to G3) exhibit homogeneous microstructure.

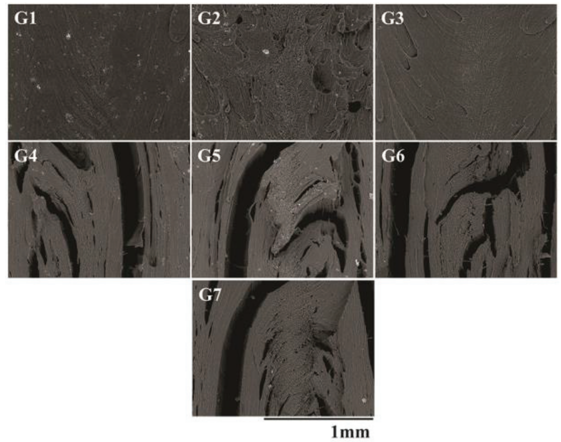

FIGURE 4 – Microstructure from composition groups.

The G2 group shows porosities, probably because its composition is 100% recycled material which presents previous thermal degradation. Groups containing SBS (G4 to G5) exhibit lamellar appearance and voids, what evidences low adherence among the components. Moreover, this microstructure does not appear to have any influence on the mechanical performance of the material, considering satisfactory results obtained for impact strength and modulus of elasticity.

Second Stage

Based on mechanical behavior of samples that have been studied at first stage, the G5 group was chosen to be submitted to RCM. G5 provides performance similar to G6 and G7, however its composition consists of higher recycled material content (25%) and lower SBS content (5%) which allows the maximum use of post consumer material and less use of virgin material. The RCM spectra analysis is not conclusive concerning the presence of degradative reactions. The main peaks appear in all FTIR test from RCM. This feature may be related to SBS addition that potentiates the presence of butadiene in the system. The thermal stability was observed in all processing cycles whose curves were near those observed for the thermal profile of ABS.

The values of the modulus of elasticity and impact strength tend to fall as the material is reprocessed, Fig. 5. This decrease may be related to material degradation such as reduction of an elastomeric phase of butadiene, which is sensitive to thermodegradation and has a strongly influences the final performance of the material [7].

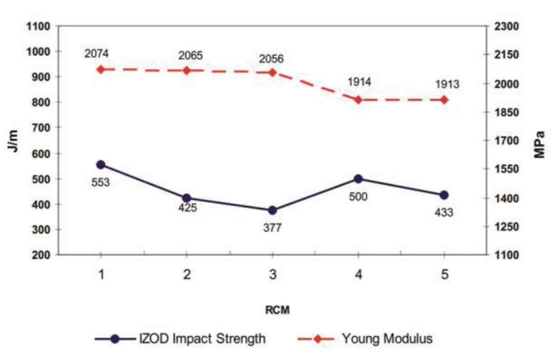

FIGURE 5 – Mechanical properties to RCM.

In RCM1, RCM2 and RCM3, the impact strength is maintained above the reference value (G1= 364 J/m shown in Fig. 3). As the material follows a trend, in RCM4, virgin material was added in the same proportion as the initial composition of G5 group. In such case, RCM3 corresponds to 25% of the total composition regarding the proportion of recycled material in the G5 group. Thus the RCM4 composition: 25% of RCM3, 70% of G1 and 5% of SBS.

The Young Modulus is the same to RCM4 and RCM5 indicating that the addition of virgin material does not improve this property at reprocessed material. In RCM4, the impact energy increases considerably after adding virgin material, reaching a value close to the initial value, the same is observed for CRM5. This behavior suggests that it is possible to adopt this procedure - adding virgin material after three reprocessing cycles; however the material stiffness tends to drop.

The morphology to RCM products can be observed in Fig. 6. The lamellar microstructure observed in RCM1 becomes homogenous in RCM2 and RCM3. When virgin material (ABS/PC) and SBS are added in RCM4, the microstructure becomes lamellar and void again.

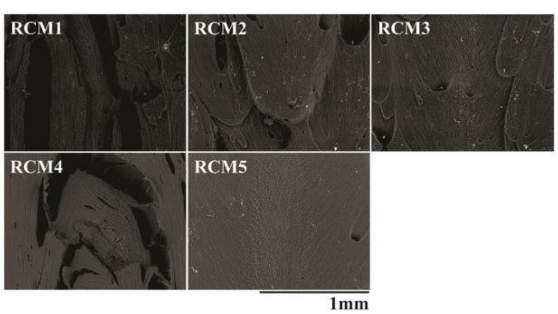

FIGURE 6 – Microstructure from RCM.

This occurrence confirms the assumption that a prior processing is required to homogenization of the mixture when SBS is added. It also reaffirms that the lamellar microstructure does not reduce the performance of the material, whereas in CRM4 mechanical performance improvement over the impact energy. It also reaffirms that the lamellar microstructure does not reduce the material performance, as observed in RCM4 and RCM5.

CONCLUSIONS

At the first stage, the FTIR spectra comparison confirms the compositions of the groups G1, G2, G3, G4, G5, G6 and G7 by the presence of peaks from ABS, PC and SBS. TGA curves exhibit thermal stability. Groups without SBS content had shown higher Young Modulus but lower impact strength. The impact strength tends to be improved when SBS is added up to 10%. Lamellar appearance and voids was observed on the microstructure of groups containing SBS, however this factor does not seem to affect the mechanical performance of these materials.

At second stage, RCM model was applied to G5 group due its satisfactory results to impact IZOD and other characteristics similar to others groups and also due its composition with higher recycled material content (25%). The results indicate no changes in FTIR peaks as the RCM was applied. The stability thermal was observed at five reprocessing cycles. The Young Modulus is reduced gradually and IZOD impact strength declines sharply as the material is reprocessed. With virgin material addition at fourth cycle (RCM4) occurs an improvement of impact strength, but the elasticity modulus is stabilized. From RCM2, the microstructure becomes homogeneous and in RCM4 the adding of SBS promotes the lamellar aspect again, disappearing in RCM5.

This article seeks to draw attention to the need to know material properties and extend its life cycle. Thus, by providing access to these information, strategies for use of this material, the recycling costs and routes can be planned locally and globally.

ACKNOWLEDGEMENTS

The authors thank CNPq, FAPERGS and Finep for financial and technical support.

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