Effect of Recycled Poly(propylene) on the Properties of a Clay Nanocomposite

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Summary: Polyamide (PA6) and poly(propylene) (PP) blends offer a good opportunity for the development of materials with new properties when they are made compatible, because they combine the thermomechanical properties of the PA6 and the easy processing of poly(propylene).[1–5] Moreover, in recent years has successfully managed to synthesize various types of composites based on clay with a polymer matrix. The aim of this work has been the incorporation of the clay in PA and PP blends to study the effect of its incorporation to establish a correlation between the morphology of the blends with the thermal and mechanical properties. To improve the incompatibility between the PA and the PP has been necessary to introduce a graft poly(propylene) – maleic anhydride compatibilizer (PP-g-AM).[6–8] In addition we have studied the incorporation of recycled PP in the system and the results were similar to those obtained with non-recycled poly(propylene).

Keywords: clay; mechanical properties; morphology; polyamides; poly(propylene)

Introduction

Recent research in the field of composite materials have found that blends of thermoplastic polymers with different thermal and mechanical properties can lead to improvements in the new composite obtained. However, mixtures of these polymers are not usually miscible and therefore we need to introduce a compound which allows a partial miscibility between the polymers. This new compound is a compatibilizer, which, in our case, is polypropylene functionalized maleic anhydride (PP-g-AM). The compatibilizer allows the interfacial tension between the matrix and the dispersed phase decreases by making the domains of the dispersed phase in the mixture become smaller.

Moreover, some researchers, in particular in the automotive industry, are incorporating natural clays in polymeric materials, since it is a cheap material and some have particular properties.

In this work we have studied the incorporation of montmorillonite (MMT) to mixtures of PA6/PP using a compatibilizer. This clay has the property of swelling in aqueous medium to a volume twenty times the initial.[9] This increase in volume causes an increase in delamination. The introduction of this clay in polymer blends causes an improvement in their final properties. The incorporation of the material was by melt process. The ratio of homopolymers was PA6/PP: 60/40 and it was precisely because with this relationship we have obtained the best results in previous studies. Once the mixture was made with the aid of a single screw extruder, was injected and were characterized by standard tests.

The research was repeated using, this time, recycled polypropylene (PPr). Our aim is to verify if the polymer can be reused without significant loss of properties in its end use.

The mechanical properties of blends have been studied by measurements of tensile, Charpy impact strength and Shore

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D hardness. Besides using scanning electron microscopy (SEM) has analyzed the morphology of such compounds.

Experimental Part

Materials

For the implementation of the different blends has been used polyamide 6 (Technyl C216), which we will call hereafter by PA6, supplied by Rhodia; polypropylene (PP) used was the PB-110H2E supplied by Repsol-YPF. The coupling agent used (G-3003) was polypropylene functionalized with maleic anhydride and provided us Eatsman Chemical Co., it was added to 0–1.0–1.5 phr. Sodium montmorillonite (MMT) used was K-10 supplied by Aldrich.

Processing

After drying the pellets in a vacuum oven at 70 °C for 12 hours, blends were prepared in a Standard Davies Co. extruder, with a single screw of 18 mm diameter, and with three zones of temperature regulated separately from the nozzle and with a cooling basing. The mixing process was performed by regulating the temperature ($250 \pm 5\,°C$) and velocity (20 ± 5 rpm). Polymers, compatibilizer and clay have been introduced into the hooper of the extruder at the same time. To achieve a greater homogeneity of the material, we should repeat extrusion process a total of three times. This has required the help of a pelletizer (Mallincrodt); once extruded material is pelletized and dried in the oven about 2 hours at 70 °C and we repeat the process. The tensile test pieces were manufactured at a pressure of $(1070 \pm 70) \cdot 10^5$ Pa and $237 \pm 2\,°C$ in an automatic injection molding, Battenfeld Plus 250, that has mold designed according to the geometry established by the UNE 53023–86. It has been considered the norm UNE 53003-ISO 291, the packaging of tensile test pieces and atmospheres of the tests.

Mechanical Tests

The tensile modulus of the samples under study was measured in a Universal Testing Machine, Ibertest mod. ELIB 50W (UNE 53023), at a rate of 1 mm/min with an axial extensometer, Ibertest mod. MFA 25, in an enclosure properly prepared for such trials.

The impact strength was made under standard UNE 53021 on a "Jaume Bot i Riera" Charpy pendulum of 7.5 J. The test pieces did not require breaking notch impact.

The indentations have been made to different blends were measured according to standard UNE 53310, corresponding to the Shore D hardness for thermoplastic polymers with a Bareiss L-61 equipament supplied by Neurtek.

Morphology

The morphology has been studied using scanning electron microscopy (SEM) with a Jeol 5510. The surface of samples of breakage of the tensile test pieces was sputtered with Au/Pd plasma to improve conduction of the electron beam.

Results and Discussion

Mechanical Tests

The values of Table 1, shows the results obtained in the different mechanical tests performed for each sample. Thus we can see how, in general, the elastic modulus, tensile strength and Charpy impact strength increase as we introduce the compatibilizer into the mixture. Weaker increase we get in the measurement of Shore D hardness. Introduction into the mixture of homopolymers the coupling agent causes the interfacial tension between the matrix and the dispersed phase decreases. This achieves a more homogeneous mixture and thereby improves the mechanical properties of the final composite.

Values obtained for different mechanical tests.

The addition of clay also involves an improvement in the mechanical properties of the mixture (from 4 to 10%). This increase is even greater when the blend contains the coupling agent. Likely, in view of data obtained, the clay is mechanically

Table 1.
Values for mechanical tests.

PA 6 (%)	PP (%)	Recycled PP (%)	G-3003 (phr)	MMT (phr)	Youngś Modulus (Mpa)	Tensile Strength (MPa)	Charpy Impact Strength (kJ/m^2)	Shore D hardness
60	40	–	0	0	874,24	25,39	24,53	64,4
60	40	–	1	0	1135,88	30,87	26,85	64,7
60	40	–	1,5	0	1170,49	34,23	33,2	65
60	40	–	0	3	912,68	24,29	22,84	63,9
60	40	–	1	3	1229,42	33,81	26,84	65,6
60	40	–	1,5	3	1289,41	36,97	34,7	67,2
60	–	40	0	3	789,06	21,57	16,26	65,4
60	–	40	1	3	1078,54	23,33	19,92	66,1
60	–	40	1,5	3	1090,64	26,02	22,39	66,6

anchored to the matrix of polyamide 6, since numerous studies have shown that if the clay is exfoliated in the matrix, the values of mechanical properties should be even higher.[10]

Moreover, the use of recycled polypropylene in the blend leads a slight decrease of mechanical properties measurements. These results are due to partial degradation suffered by the material in recycling processes. However, the values obtained with recycled polypropylene are good enough to be used in various applications that no require high mechanical performance, generating a lower cost of raw materials.

Morphology

Micrographs of the Figure 2 show that the MMT is anchored mechanically to the polyamide matrix, and the domains of dispersed phase are very large. But when we introduce the compatibilizer, Figure 3, the size of these spherical domains decrease. It is observed that the spherical domains, in Figure 3 right, are smaller than we were working with recycled polypropylene, confirming the mechanical results.

Conclusion

It has been shown that introduction of a coupling agent in a binary mixture of polymers provides enhanced mechanical properties of the material. Has also succeeded in introducing a natural clay in these mixtures, improving the mechanical properties of the final product, although the

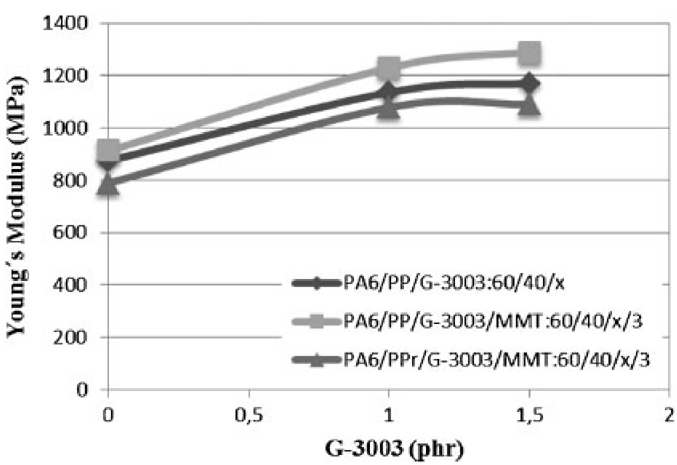

Figure 1.
Influence of compatibilizer in the Youngś Modulus values.

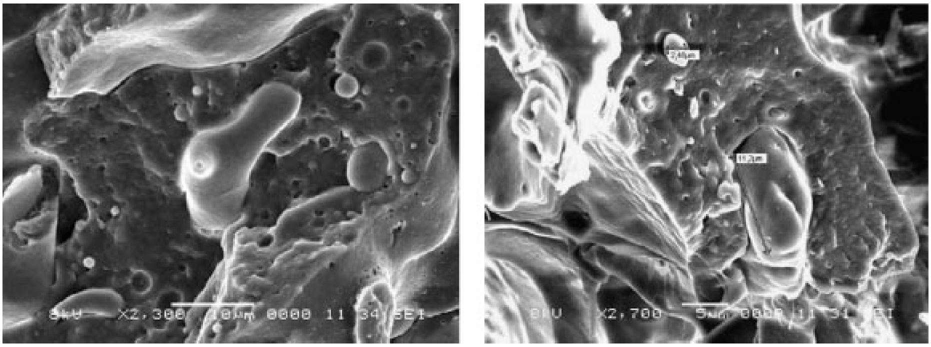

Figure 2.
SEM micrography of PA6/PPr/G-3003/MMT: 60/40/0/3 on the left, and PA6/PP/G_3003/MMT: 60/40/0/3 on the right.

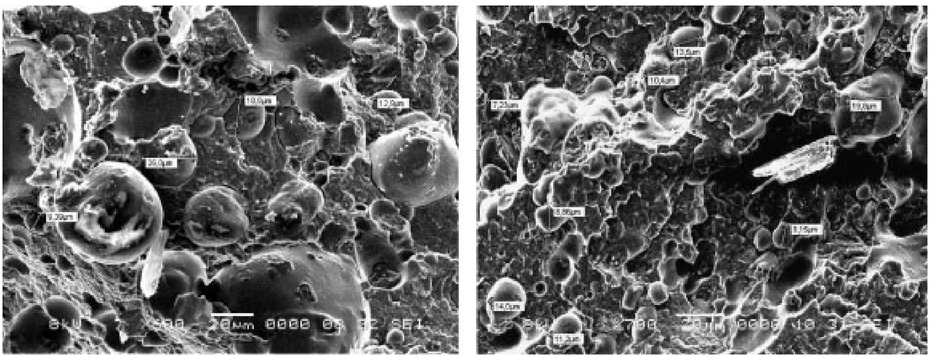

Figure 3.
SEM micrography of PA6/PPr/G-3003/MMT: 60/40/1,5/3 on the left, and PA6/PP/G-3003/MMT: 60/40/1,5/3 on the right.

results were lower than expected because the MMT was mechanically anchored to the matrix and therefore not achieved an exfoliation of layers of the clay.

Recycled PP was used and found that good results were achieved in mechanical properties. This opens door to their use in certain areas getting a lower cost of material.

[1] J. Rosch, *Polym. Eng. Sci.* **1995**, *35*, 1917.
[2] S. C. Wong, Y. W. Mai, *Polymer* **2000**, *41*, 5471.
[3] S. C. Wong, Y. W. Mai, *Polymer* **1999**, *40*, 1553.
[4] J. Rosch, R. Mulhaupt, *Polymer Bull* **1994**, *32*, 697.
[5] F. P. Tseng, J. J. Lin, C. R. Tseng, F. C. Chang, *Polymer* **2001**, *42*, 713.
[6] P. F. Salas, I. Mondragon, M. L. González, A. Valea, *Anales de la Mecánica de la Fractura*, **2005**, *22*, 459.
[7] R. M. Holsti-Miettinen, J. V. Seppala, O. T. Ikkala, I. T. Reima, *Polym. Eng. Sci.* **1994**, *34*, 395.
[8] O. T. Ikkala, R. Holsti-Miettinen, J. Seppala, *J. Appl. Polym. Sci.* **1993**, *49*, 1165.
[9] B. González, A. Valea, I. Mondragon, M. L. González, *X Congreso Nacional de Materiales*, **2011**, *1*, 533.
[10] M. Alexander, P. Dubois, *Mater. Sci. Eng.* **2001**, *28*, 1.