Mechanical and Rheological Behavior of Polypropylene / Montmorillonite Nanocomposites Prepared Through 'Master Batch' Approaches

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Abstract

Fundamental studies of the 'Master Batch' (MB) approach to form polymer inorganic nanocomposites are presented. In particular, the molecular weight (M_w) difference between matrix (polypropylene, PP) and functionalized polymer (functionalized polypropylene, F-PP) in the master batch was systematically investigated, and the effects of this M_w-difference on composite structure and material properties were studied. PP / F-PP / organophilic montmorillonite (OMMT) nanocomposites were prepared from one F-PP / OMMT master-batch by melt-compounding with various neat PPs. Three kinds of PPs having different molecular weights (M_w) were used as the matrix. Morphological studies revealed coexisting intercalated and exfoliated OMMT layers for all PP matrices, with better OMMT dispersion for the higher M_w PP. These dispersion differences are also reflected in the rheological behavior, and in higher enhancements of tensile modulus for the higher M_w PP matrix (i.e. 20% increase of tensile modulus at 5wt% OMMT).

1 Introduction

The large commercial importance of polypropylene (PP) has been driving an intense study of PP nanocomposites reinforced with inorganic fillers (especially layered silicates). However, since there is no strong interaction between hydrophobic PP and these hydrophilic inorganic fillers, a lot of effort has been invested into optimising the filler dispersion in PP.
In this study, PP / functionalized-PP (F-PP) / organophilic montmorillonite (OMMT) nanocomposites were prepared through the ‘Master Batch’ approach, focusing on well-defined model MB systems. Structure-property relationships of PP / F-PP / OMMT nanocomposites are discussed herein, with the emphasis on the molecular weight (M_w) difference between PP matrix and F-PP used as a ‘compatibilizer’ polymer in the master batch.

2 Experimental

2.1 Materials

Isotactic polypropylenes (PP) having different molecular weight (M_w) and functionalized polypropylene (maleic anhydride-modified PP; F-PP) were used. The characteristics of PP and F-PP are shown in Table 1. The organophilic montmorillonite (OMMT) was a commercial material, Nanomer® I44PA (Nanocor), with a 1.4meq/g of dimethyl-dioctadecyl-ammonium organic modification (as reported by the supplier).

PP		M_w $\times 10^5$
H-PP	High M_w PP	2.43
M-PP	Medium M_w PP	1.62
L-PP	Low M_w PP	1.39
F-PP	Maleic anhydride-modified PP	1.51

Table 1: Molecular weights and assignments for the PP and F-PP polymers.

2.2 Preparation of PP / Montmorillonite nanocomposites

A F-PP / 15wt% OMMT master batch was prepared using a Brabender Plasticoder twin-head kneader, operated at 200°C for 15min. This master batch was let down with various PP in order to obtain PP / F-PP / OMMT nanocomposites (67/28/5 wt%). Unfilled PPs, and PP / F-PP (70/30 wt%) blends were also processed in the same manner and were used as controls.

2.3 Characterization

X-ray diffraction and transmission electron microscopy measurements indicated that PP / F-PP / OMMT nanocomposites had an intercalated and exfoliated structure. Differential scanning carolimetry (DSC) was performed in a TA 100 under a nitrogen atmosphere. Tensile testing was conducted using an Instron Universal tensile tester at a crosshead speed of 25 mm/min (ASTM D-638). Melt-state rheological measurements were performed on a Rheometric Scientific ARES rheometer.

3 Results and Discussions

Figure 1 compares the tensile moduli of the nanocomposites against the respective polymer blends. The increased tensile modulus of the nanocomposites is attributable to the combined effects of increased crystallinity and mechanical reinforcement, caused concurrently by the OMMT fillers (Figure 1). The largest modulus enhancement was observed for the higher Mw H-PP composites compared to the M-PP and L-PP matrices. H-PP composites also exhibited the best OMMT dispersion, as seen by TEM and as manifested in rheological studies.

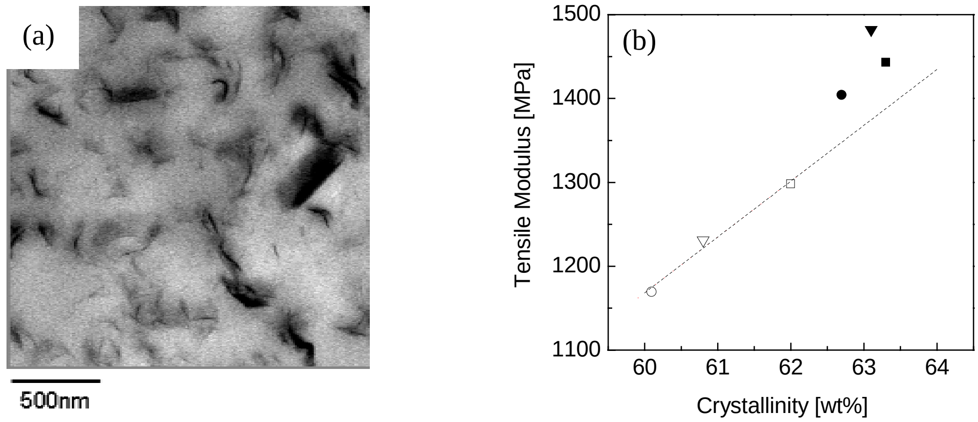

Figure 1: (a) TEM image of H-PP/F-PP/OMMT nanocomposite (67/28/5wt%) (b) Tensile modulus of 70/30 PP/F-PP blends (open) and 67/28/5 PP/F-PP/OMMT nanocomposites (solid) as a function of their crystallinity. The PP M_w is varied [H-PP (triangles), M-PP (circles) and L-PP (squares)]. The dashed line follows the blend behavior, whereas crystallinity was estimated by DSC (enthalpy of fusion for 100% crystalline PP: 208J/g)

4 Conclusions

The effects of the M_w-difference between PP and F-PP on structure and material properties of PP / F-PP / OMMT nanocomposite were studied. Higher enhancement of tensile modulus for the higher M_w PP matrix was observed (i.e. 20% increase of tensile modulus at 5wt% OMMT). Rheological studies showed better OMMT dispersion for the higher M_w PP matrix (in comparison with M_w of F-PP) and this result supports the tensile testing results.

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