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EFFECT OF THE ELONGATIONAL FLOW ON MORPHOLOGY AND PROPERTIES OF NANOCOMPOSITES CONTAINING LDHs

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Introduction

Polymer-based nanocomposites are becoming increasingly popular due to their several advantages in terms of weight, costs and entailing mechanical reinforcement as compared to traditional composites. In fact, the incorporation of a nano-filler within a polymer matrix implies the establishment of strong interactions at the interface. In particular, when layered nanofillers (such as clays or hydrotalcites) are considered, the polymer chains are able to enter the interlayer galleries, causing a reduction of the electrostatic interactions between the layers. In this case, nanocomposites having intercalated or partially exfoliated microstructure with excellent mechanical properties are obtained [1]. However, one of the main issues concerning the processing of polymer-based nanocomposites is the formation of filler aggregates and agglomerates, which lead to uneven and inhomogeneous morphologies negatively affecting the final properties of the material [2]. As widely documented in literature, the application of the elongational flow during the processing is effective in inducing microstructural evolution in both homogeneous polymer and multi-phasic systems, such as polymer blends or polymer-based composites. More specifically, several studies demonstrated the effectiveness of the elongational flow in ameliorating the state of dispersion of micro- and nano-fillers in polymer-based composites. In particular, especially for composite systems containing anisotropic fillers, the application of the elongational flow brings about some preferential orientation of the embedded particles along the flow direction, with beneficial effects on the overall performances of the material. Furthermore, it has been observed that these effects are further pronounced when the elongational flow is applied in non-isothermal conditions [3].

At present, most of the investigations in this field concerns polymer/clay nanocomposites, since they show a peculiar behavior when subjected to elongational flow, which is completely different from that of other filled polymer-based systems containing different types of particles; at variance, a very limited amount of studies regards elongational flow-induced effects on nanocomposites containing hydrotalcites (LDHs).

In this work, PP-based composites containing 6 or 12 wt.% of LDHs modified with stearate or oleate (MgAlstea or MgAlole) functional groups (supplied by Prolabin&Tefarm) were prepared through melt compounding. The melt extrudates were then

subjected to non-isothermal elongational flow through an elongational rheometer Rheospin. The morphology and mechanical properties of the collected fibers were thoroughly investigated and compared with those of as-extruded isotropic samples, aiming at verifying the possible effect of the elongational flow on the microstructure and final performance of the formulated nanocomposites.

Results and discussion

Firstly, the morphology and the rheological properties of the isotropic as-extruded materials were characterized. XRD analyses highlighted the obtainment of intercalated or partially exfoliated structures, especially in nanocomposites containing 12 wt.% of MgAlole, as indicated by signals shift in XRD spectra. SEM observations indicated the achievement of a good extent of nanofiller dispersion and distribution, notwithstanding the presence of some agglomerates at micrometric scale, especially in the nanocomposites containing high LDHs loadings (Figure 1).

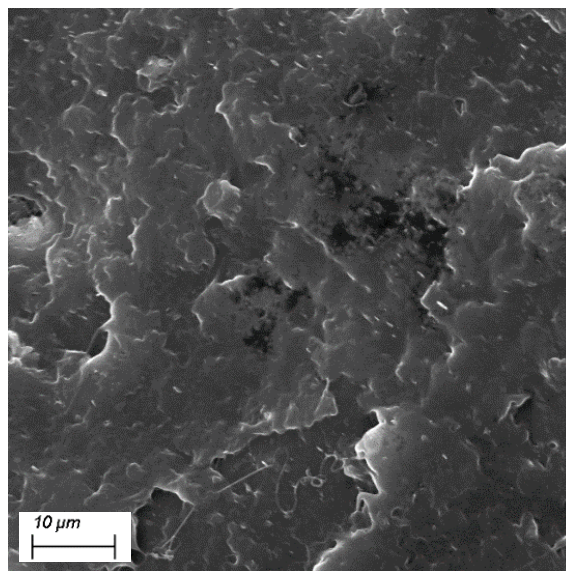


Figure 1: SEM micrograph of PP+6% MgAlole.

The analysis of the rheological behavior of LDHs-containing nanocomposites confirmed the obtainment of a homogeneous morphology. In fact, as observable in Figure 2, the incorporation of increasing amounts of LDHs caused the disappearance of the Newtonian plateau of the matrix and the occurrence of an apparent yield stress behavior in the low frequency region. This last is indicative of strong

matrix/filler and filler/filler interactions, which are able to slow down the dynamics of the polymer macromolecules, hindering their complete relaxation. At variance, in the high frequency zone, the shear thinning behavior of the nanocomposites is more pronounced as compared to the unfilled matrix due to the slipping action of the well-dispersed platelets which favours the alignment of the PP macromolecules along the flow lines.

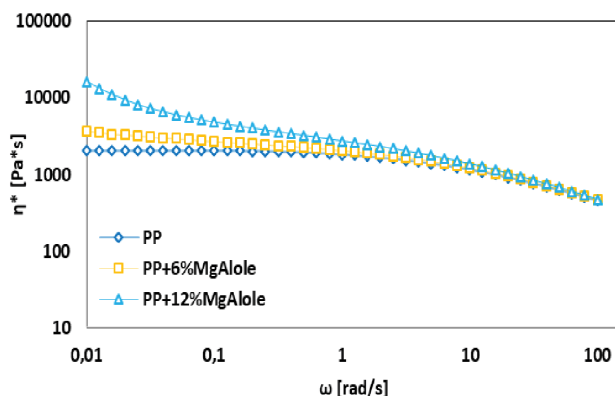


Figure 2: Complex viscosity curves for the MgAlOle-containing nanocomposites. The complex viscosity of the unfilled PP is also reported.

Nanocomposite fibers produced at different values of draw ratio (DR) have been subjected to tensile test and the trend of the dimensionless tensile strength (obtained as the ratio between the tensile strength of the fibers and that of the corresponding isotropic material) as a function of DR is reported in Figure 3.

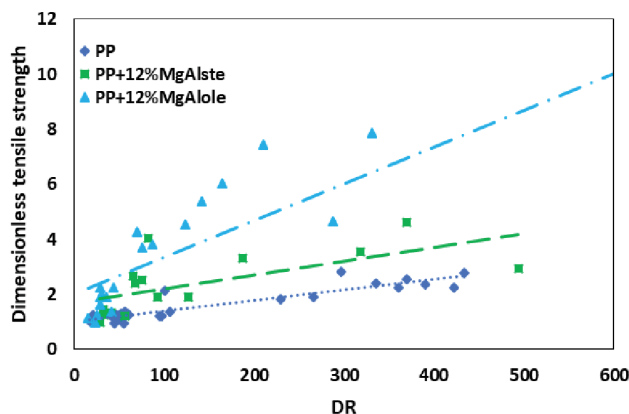


Figure 3: Dimensionless tensile strength as a function of DR for unfilled PP and MgAlOle-containing nanocomposites.

First of all, regardless of the DR value, the tensile strength of the nanocomposites is higher as compared to that of the unfilled PP, especially for the systems containing MgAlOle. On the other hand, as a function of DR, the tensile strength shows an increasing trend for both unfilled PP and nanocomposites. For the matrix, this result can be ascribed to the progressive chains orientation and alignment

along the fiber direction [3]. As far as the behavior of the nanocomposites is concerned, the values of tensile strength tend to rise with increasing DR in a more pronounced and rapid way as compared to the unfilled PP, highlighting the effectiveness of elongational flow in inducing a preferential orientation of the PP chains, as well as of the embedded LDHs platelets, along the flow direction.

Besides, it can be inferred the occurrence of a sort of tearing/slipping mechanism, well documented for polymer/clay nanocomposites, involving a progressive enhancement of intercalation/exfoliation. In particular, the application of the elongational flow promotes the increase of the interlayer distance in the tactoids and intercalated structures present in the as-extruded nanocomposites, giving rise to the formation of exfoliated morphologies or highly intercalated structures, characterized by a higher interlayer distance with respect to the isotropic materials. The formation of exfoliated arrangements and the increase of the interlayer distance in intercalated structures upon extension has been explained in polymer/clay nanocomposites considering that these systems, when subjected to the elongational flow, show an intermediate behavior between that of a “traditional” composite material, containing non-deformable particles that can be oriented along the flow direction, and that of polymer blends, in which the dispersed phase can be deformed, broken and oriented by the action of the flow.

The improved dispersion of the LDHs particles after stretching has been confirmed by SEM analysis. In fact, the disappearance of the filler aggregates present in the isotropic materials, as well as some preferential orientation of the LDHs platelets was observed, especially in nanocomposites containing MgAlOle.

Conclusions

PP-based nanocomposites containing different loadings of organo-modified LDHs were produced through melt compounding and subjected to elongational flow. The preliminary characterization of the isotropic materials pointed out the achievement of a good extent of filler dispersion, as well as the establishment of strong polymer/filler and filler/filler interaction. The mechanical characterization of the nanocomposite fibers indicated a beneficial effect of the elongational flow in inducing a preferential orientation of the embedded filler in the flow direction and an enhancement of the exfoliation/intercalation, thus promoting the achievement of superior properties.

References

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