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INFLUENCE OF MIXING CONDITIONS IN TWIN-SCREW EXTRUSION OF POLYPROPYLENE/CARBON NANOTUBES COMPOSITES

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KEYWORDS

Carbon nanotubes, polymer composites, dispersion.

ABSTRACT

Composites prepared in different mixing conditions are compared to study the dispersion of carbon nanotubes in polypropylene. The effect of nanotube surface modification and compatibilization with polypropylene modified with maleic anhydride is also studied. The dispersion of the nanotube agglomerates through the polymer, the electrical and the mechanical properties of the resulting composites achieved under the different mixing conditions are analyzed. A large improvement of the nanotube dispersion is observed using high screw speed conjugated with low throughput, as compared with other operating conditions. Moreover the use of functionalized carbon nanotubes drastically increased the nanotube dispersion.

INTRODUCTION

It is known that carbon nanotubes (CNT) present excellent mechanical, electrical and thermal properties. However, their polymer composites do not always present the expected property enhancement. The large effort dedicated to the study of polymer/CNT composites along the past years has shown the enormous influence of the processing methods and conditions on the composite properties (Kasaliwal et al. 2009). The present work reports the study of the dispersion of carbon nanotubes, as-received and chemically functionalized (FCNT), in polypropylene (PP) using different mixing conditions. Composites were prepared using an small-scale twin-screw extrusion. The composites formed using different mixing conditions are compared in terms of CNT distribution and dispersion, electrical and mechanical properties.

EXPERIMENTAL

Composites with CNT (NC 7000 from Nanocyl®) and PP, and chemically modified CNT and PP blended with PP-g-MA were prepared. The chemical functionalization was performed under solvent-free conditions, as described elsewhere (Paiva et al. 2010). The functionalized CNT, containing pyrrolidine functionality at their surface, are expected to react with the maleic anhydride grafted to the PP (Paiva et al. 2010).
Composites of PP with CNT, PP blended with PP-g-MA and chemically modified CNT, were produced. The composites with FCNT were prepared using two different approaches: i) melt mixing of PP + PP-g-MA + FCNT and ii) mixing of FCNT and PP-g-MA in solution followed by extrusion with PP. Melt-mixing was carried out on a bench-top prototype modular co-rotating twin screw extruder designed to process small amounts of material while retaining the same characteristics of larger machines coupled to a miniaturized volumetric feeder. The screw comprises conveying elements and kneading blocks for melting/dispersive action. The composites extrusion was performed varying the flow rate (40 and 130 g/h) and screw speed (20 and 80 rpm). Test specimens for optical microscopy (OM) analysis, electrical resistivity tests, scanning electron microscopy, and tensile tests were prepared by compression molding. The influence of the operating conditions and the modification of CNT on the distribution, dispersion, and primary agglomerate size was analyzed by OM.

RESULTS

The observation of the composites using OM allowed the study of CNT agglomerate distribution and dispersion. The effect of the operating conditions on the CNT distribution, dispersion, and primary agglomerate size was analyzed (Fig. 1 and 2) demonstrating a remarkable influence of the operating conditions on the dispersion level attained. The number and also the area

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of the remaining agglomerates can dramatically decrease by using the proper screw speed and throughput.it was observed that to obtain a much larger fraction of individual dispersed CNT, the most favorable conditions corresponds to the conjugation of high rotation speed and low throughput. The effect of chemical modification was also analyzed (Fig. 1 and 2) illustrating better dispersion of FCNT, in particular for the FCNT/PP-g-MA composite.

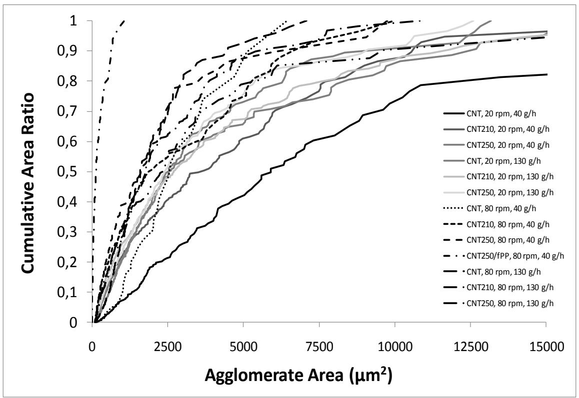

Figure 1: Cumulative area ratio for composites with 4 wt% CNT processed in different operating conditions, with pure or functionalized CNT.

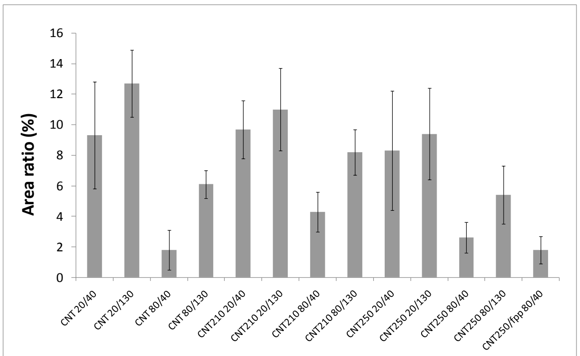

Figure 2: Total agglomerate area ratios obtained for the composites with 4 wt% of pure or functionalized CNT processed in different operating conditions.

The electrical resistivity (Fig. 3) of the composites was measured as well as the mechanical proterpties (Fig. 4). The electrical percolation of these composites varies between 2 and 3 wt%, placing the composites with non functionalized and functionalized CNT in the conductive behavior region. For PP/CNT composites the tensile modulus does not enhanced, while for FCNT/PP-g-MA composite, 40% enhancement in elastic modulus was observed due to the increase in dispersion mentioned above.

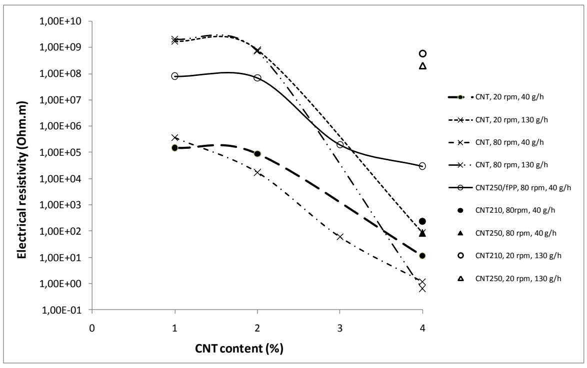

Figure 3: Electrical resistivity for CNT/PP composites with filler contents between 1 and 4 wt% prepared with different operating conditions.

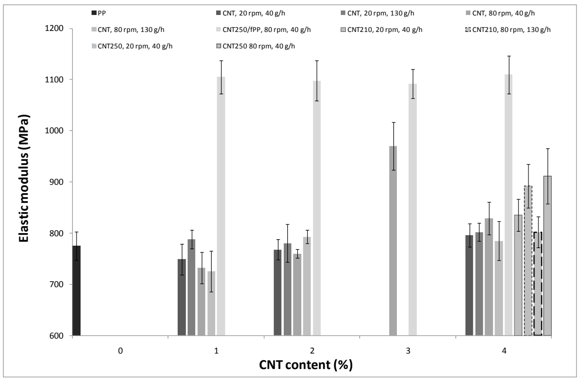

Figure 4: Elastic modulus for CNT/PP composites with filler contents between 1 and 4 wt% prepared with different operating conditions.

REFERENCES

Kasaliwal, G.; A. Göldel; and P. Pötschke. 2009. Influence of processing conditions in small-scale melt mixing and compression molding on the resistivity and morphology of polycarbonate–MWNT composites. *Journal of Applied Polymer Science*, 112, 3494–3509.

Paiva M. C.; R. M. Novais; R. F. Araújo; K. K. Pedersen; M. Proença; C. J. R. Silva; C. M. Costa; and S. Lanceros-Méndez. 2010. Organic fuctionalization of carbon nanofibers for composite appications. *Polymer Composite*, 31, 3, 369-376.

Paiva M. C.; F. Simon; R. Novais; T. Ferreira; M. Proença ; W. Xu; and F. Besenbacher. 2010. Controlled functionalization of carbon nanotubes by a solvent-free multicomponent approach. *ASC Nano*, 4, 12, 7379-7386.