Chemical functionalization of carbon nanotubes and its influence on composite properties

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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 [1-3].
The present work reports the study of the dispersion of carbon nanotubes, as-received and chemically functionalized (FCNT), in polypropylene (PP) using two different melt mixing methods. Composites were prepared using small-scale twin-screw extrusion and a lab scale microcompounder. The composites formed using the two different methods are compared in terms of CNT distribution and dispersion, electrical properties and CNT/polymer interface.

Experimental

Composites with CNT (Nanocyl NC 7000) 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 [4]. The functionalized CNT, containing pyrrolidine functionality at their surface, are expected to reactd with the maleic anhydride grafted to the PP according to the scheme proposed (Fig. 1) [5].

Composites of PP with CNT and PP blended with PP-*g*-MA and chemically modified CNT were produced. 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 (screw diameter = 12 mm, output range 30 – 400 g/hr) coupled to a miniaturized volumetric feeder. The screw comprises conveying elements and kneading blocks for melting/dispersive action. Composites were also melt mixed in a lab scale microcompounder, DSM MICRO 5, with a net barrel capacity of 5 cm^3, using a speed of 50 rpm and a fixed mixing time of 5 min. Test specimens for OM analysis, electrical resistivity tests, scanning electron microscopy, and tensile tests were prepared by compression molding.

The influence of the functionalization of CNT on the distribution, dispersion, and primary agglomerate size was analyzed by optical microscopy (OM). Depending on the processing conditions, composites prepared with 2-4% CNT presented electrical conductivity. Scanning electron microscopy evidenced the enhanced phase adhesion induced by the CNT functionalization.

Results

The observation of the composites using OM allowed the study of CNT agglomerate distribution and CNT dispersion. The effect of the processing conditions and chemical modification of the CNT was analyzed (Fig. 2) illustrating better dispersion of FCNT. Slightly smaller agglomerates were observed using the small scale extruder. The electrical resistivity of the composites was measured. Scanning electron microscopy evidenced better phase adhesion in case of the FCNT/modified PP composites (Fig. 3).

Acknowledgements
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Figures

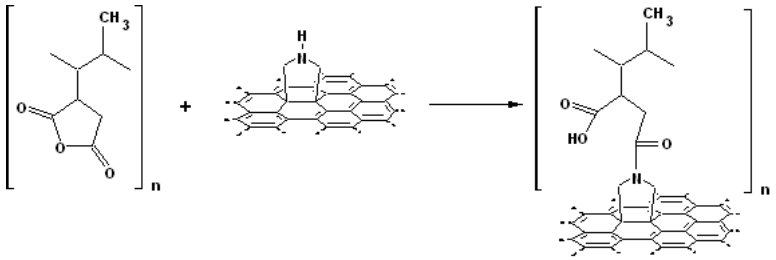

Fig. 1 Reaction of the pyrrolidine at the surface of the FCNT with the maleic anhydride grafted on PP.

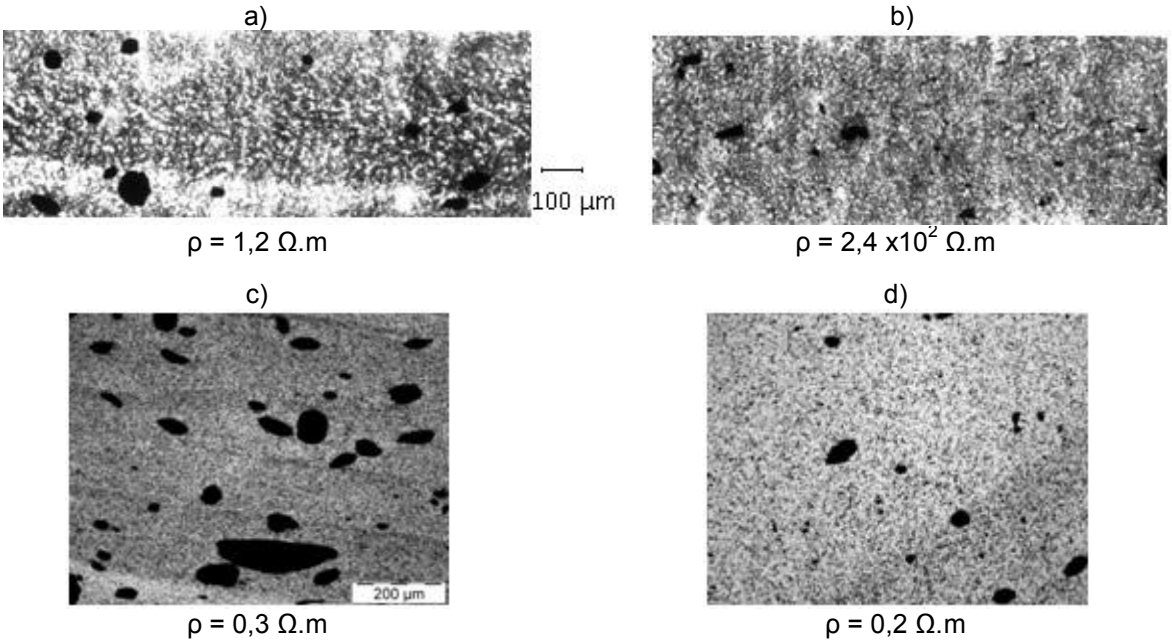

Fig. 2 Optical micrographs and electrical resistivity results of the composites prepared using twin screw extrusion with a) non-functionalized CNT and b) functionalized CNT; and prepared using the DSM micro 5 with c) non-functionalized and d) functionalized CNT, dispersed in PP.

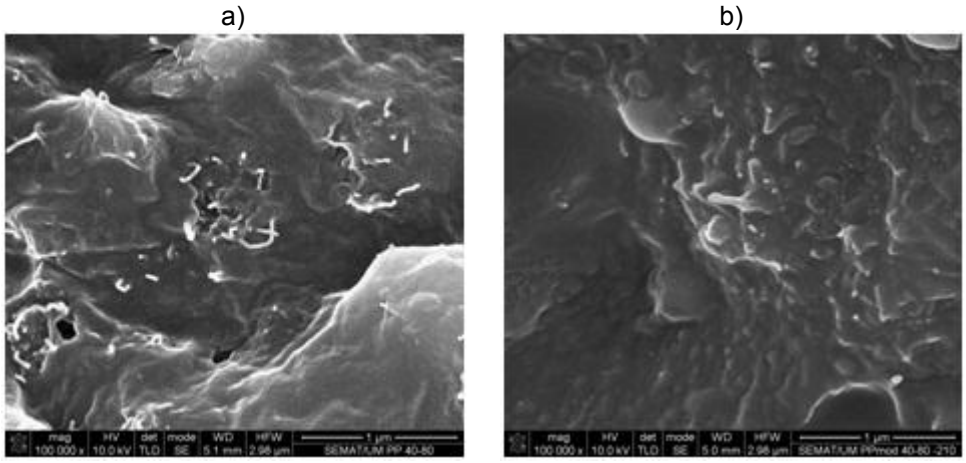

Fig. 3 SEM micrographs of the cross section of PP composites with: (a) non-functionalized CNT's, and (b) functionalized CNTs, prepared by twin screw extrusion.