Microinjection moulding of nanocomposites with modified carbon nanotubes: correlation between dispersion and electrical conductivity

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Introduction

Carbon nanotubes (CNT) exhibit unique thermal, electrical and mechanical properties, and their nanocomposites have attracted the attention of many scientists due to the strong application potential in electronics, chemical and biological sensing and reinforced composite materials[1]. The processes of micro molding (MIM) and microinjection molding (*μ*IM) are the most efficient and cost-effective processes for the large-scale production of thermoplastic nanocomposite microparts with low reinforcement content and exceptional electrical properties.

The present work reports the dispersion of CNT in polyamide 6 (PA 6) for the production of nanocomposites with different CNT content using μIM. The CNT were used as received and chemically functionalized. The nanocomposites were micro injection moulded and the electrical and mechanical properties of the specimens obtained were measured. The dispersion, distribution and interface of the CNT in the PA 6 were analysed.

Experimental

The CNT (Nanocyl NC 7000) were functionalized using the 1,3-dipolar cycloaddition reaction of an azomethine yilide to the CNT, generating pyrrolidine groups at the surface [2], under solvent-free conditions.

The nanocomposites with polyamide 6 (Badamid®B70) and pure or functionalized CNT were prepared in a prototype mini-twin screw extruder under different processing conditions; small specimens were obtained by microinjection moulding in a Boy 12 equipment (Fig. 1).

The nanotube agglomerate size, distribution and dispersion were measured using optical microscopy (OM) and the CNT/polymer interface was observed by scanning SEM. The electrical resistivity of the composites was measured. The specimens were tensile tested using a microtester equipped with a load cell of 1 kN.

Results

The images of the composites obtained by OM allowed the statistical study of CNT agglomerate size and distribution, and CNT dispersion (Fig. 2). The SEM images evidence the effect of the chemical modification of the CNT, illustrating the improvement of the CNT interface in PA 6 in the case of funcionalized CNT (Fig. 3). The improvement in CNT dispersion affected the electrical and mechanical properties of the composites, as illustrated in Table 1 for the composites with 1,5% wt of as received and functionalized CNT. As expected, the composites of PA 6 with 1,5-4,5% CNT are semiconductors, and the condutivity increased with the CNT content. The addition of pure CNT to PA 6 increased the elastic modulus and the increase was proportional to the amount of CNT incorporation. Samples with functionalized CNT presented the higher values for elastic modulus.

Fig. 1 - Microinjection moulded composite specimens: a) tensile and b) impact.

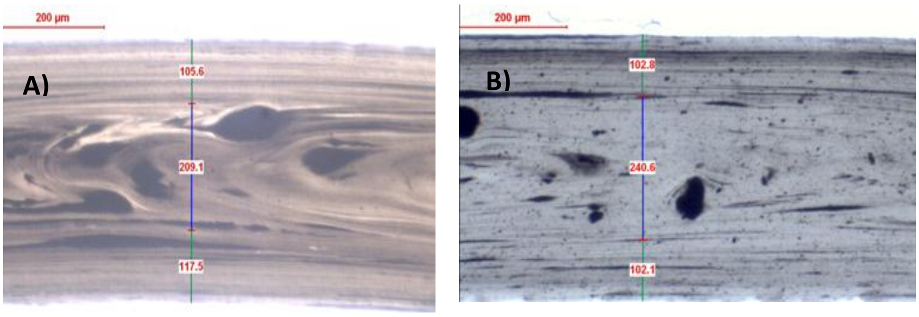

Fig. 2 – Examples of optical microscope images and statistical study for pure A) and functionalized B) 1,5% CNT nanocomposites for tensile specimens.

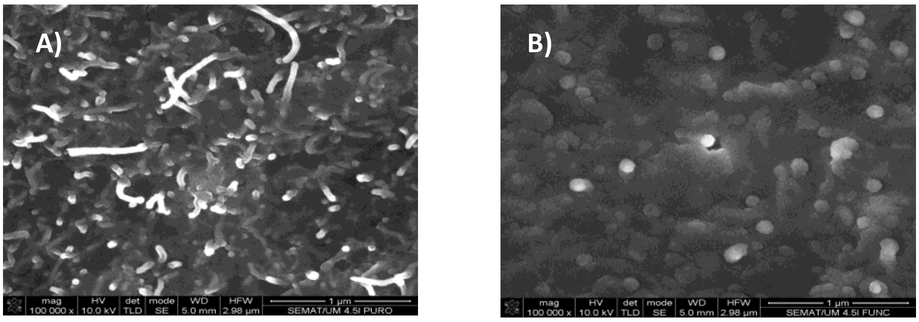

Fig. 3 – SEM images for pure A) and functionalized B) 4,5% CNT nanocomposites.

Table 1 – CNT dispersion results and electrical and mechanical properties for the nanocomposites with 1,5% of pure CNT and functionalized CNT (FCNT).

Composite	Number of agglomerates	Average area (μm^2)	Electrical conductivity ($S.m^{-1}$)	Elastic Modulus (MPa)
CNT	94	3017 ± 682	$7,3 \times 10^{-04}$	2,66 ± 0,42
FCNT*	242	839 ± 151	$1,7 \times 10^{-04}$	3,99 ± 0,64

*The CNT content in FCNT nancomposites is 1,26%, the remaining weight is due to the functional groups at the CNT surface.

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