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Effect of functionalization on the thermo-mechanical properties of multi-wall carbon nanotube/epoxy-nanocomposites

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ABSTRACT

In this paper the effect of the functionalization of multi-walled carbon nanotubes (MWCNTs) on the mechanical behaviour of epoxy-resin composites was investigated. Samples based on epoxy resin with different weight percentage of MWCNTs or COOH-functionalized MWCNTs (MWCNTs-COOH) were prepared and characterized. Dynamic-mechanical thermal analysis shows that the storage modulus increases with the addition of MWCNTs, whereas a constant value or even a weak reduction of it is observed when functionalized nanotubes are used. Experimental data show two phases for the composites with MWCNTs-COOH. Morphological investigation have shown that these results are ascribed to the modified chemical properties of MWCNTs-COOH due to the strong interconnections with the polymeric matrix.

Keywords: Multi-walled carbon nanotubes (MWCNTs), Epoxy resin, Dynamic-mechanical thermal analysis, Carbon nanotube/epoxy nanocomposites.

1. INTRODUCTION

The increased demand for high-quality multifunctional materials in different industrial applications is the driving force of the huge research effort dedicated to the formulation and preparation of advanced nanostructured composites with superior characteristics. Among thermosetting polymers, epoxy-based systems, due to their excellent mechanical properties for structural stability, allow to manufacture a very versatile class of composites for structural applications in automotive, aeronautics, marine industry, electronics and others. In particular, epoxy-based composites with very low concentrations of MWCNTs, preserving the remarkable mechanical properties and surface finish properties of the matrix and exhibiting a sufficiently high electrical conductivity (greater than 10^6 S/m), have been proposed for the dissipation of electrostatic charges, for electromagnetic shielding, electronic packaging, sensors and as structural parts in automotive and aerospace applications [1]. In this work, dynamic-mechanical properties of the epoxy systems in presence of increasing concentrations of multi-walled and chemically functionalized carbon nanotubes are discussed to enlighten the effect of functionalization, with reference to the morphological characteristics of the composites.

2. MATERIALS

The composites are manufactured by using as base epoxy resin DiGlycidil-Ether Bisphenol-A (DGEBA), with 4,4' DiaminoDiphenyl Sulfone (DDS), as hardener agent. The MWCNTs (3100 Grade) and MWCNT-COOH (3101 Grade) were obtained from *Nanocyl S.A.*

3. RESULTS AND DISCUSSION

Mechanical Properties.
The storage modulus, E' (MPa), and the loss factor, tanδ, of the neat epoxy and the composites with different MWCNT concentrations are shown in Fig. 1 (a and b). At low temperatures all the samples show a very high value of the elastic modulus, followed by two little drops due to second order transitions between -20 and 0°C the first and between 50 and 70°C the second. The principal drop, due to the glass transition, is evident for all samples in the range 220-240°C. In this temperature range also the tanδ curves show a peak indicating the glass transition temperature of the material.

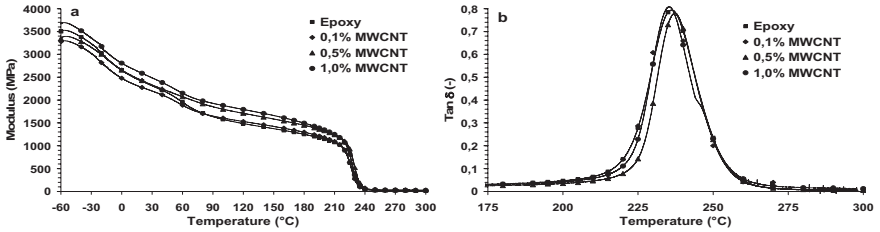

Fig. 1. (a) Storage modulus, E' (MPa) and (b) Loss factor (tanδ) of the pure epoxy and its composites with different MWCNTs concentrations.

All the samples present almost identical peak height and position in the loss factor curves. This indeed means that the MWCNTs, at the investigated concentrations, have no particular effect on the relaxation phenomena leading to the glass transition of the system. In Fig. 2 (a and b) dynamic mechanical curves of the resin with increasing concentrations of functionalized CNT are reported. Carbon nanotubes functionalized with -COOH show a different behaviour.

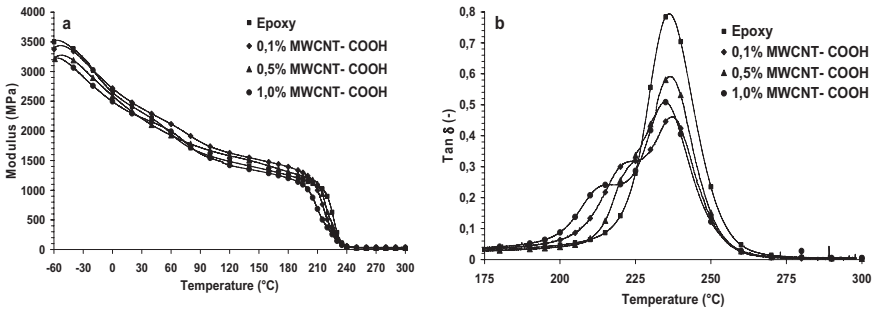

Fig. 2. (a) Storage modulus, E' (MPa) and (b) Loss factor (tanδ) of the pure epoxy and its composites with different MWCNT-COOH concentrations.

The samples with carbon nanotubes modified with -COOH groups, show two peaks in the tan δ indicating the presence of a lower temperature glass transition, beside the main transition at the same temperature as the pristine resin.
The presence of a secondary peak, active at a lower temperature, in the loss factor suggests the presence of a fraction of amorphous phase with higher mobility due to a different degree of crosslinking. It can be suggested that the presence of the -COOH groups catalyses a fraction of homo-polymerization, as hypothesized by the DSC curves (not reported here), having a lower glass transition temperature, although regarding a phase nearer to the nanotubes. It seems likely that the –COOH groups of the functionalized nanotubes induce a homopolymerization determining the formation of a more mobile phase around the nanotubes.

References

[1] Y.S. Song, J.R. Youn. Carbon 43:1378–1385 (2005).