

“Nanocomposites based on poly(ether imide) by the addition of a poly(butylene terephthalate)/carbon nanotube masterbatch: Electrical conductivity and mechanical performance”

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Abstract

Polymer nanocomposites (PNs) based on carbon nanotubes (CNTs) show exceptional properties resulting from the mixed polymer matrix and the nanostructured CNTs. These properties, mainly physical and mechanical, are clearly superior to those of conventional microcomposites.

Several processing methods have been employed to produce thermoplastics/CNT nanocomposites, such as melt mixing [1], in-situ polymerization [2], solution processing [3], etc. Among these methods, melt mixing of CNTs with thermoplastic polymers using conventional processing techniques is particularly desirable, because the process is fast, simple, free of solvents and contaminants, and available for the plastic industry [4]. In this way, the use of pre-compounded, largely dispersed master-batches (usually containing 10–20 wt.% CNTs) produced in “ad hoc” machinery is advantageous for processing, as hazardous contact with the nano-sized inclusions is reduced to the minimum, and dispersion is close to the optimum.

Poly(ether imide) (PEI) is a high performance thermoplastic with high thermal stability and remarkable modulus of elasticity and tensile strength. It performs successfully in electrical and electronics industry, in aircraft applications and in the automotive market. Development of highly performing electrically conductor PNs based on PEI via melt processing is challenging in their processing and dispersion. This is due to the high processing temperature and melt viscosity of the PEI that hinder the dispersion of the CNTs.

Widely dispersed PNs based on organoclays have been obtained by blending the desired matrix with a master-batch of a polymer that is both miscible with the matrix and able to disperse the organoclay. This technique collects together the advantages of the presence of the nanostructured filler and those conferred by blending. Moreover, it is especially effective when the production of the nanostructured master-batch lends advantages, such as easier processing or improved dispersion. It is known that PEI is fully miscible with poly(butylene terephthalate) (PBT) over the entire composition range. Moreover, highly dispersed PBT/multiwall carbon nanotube (MWCNT) master-batches are commercially available at very competitive prices. Therefore, they could be used to disperse the MWCNTs and produce PEI-rich nanocomposites.

In this work, we have obtained melt processed PEI nanocomposites using a commercial PBT/MWCNT master-batch. The MWCNT content in ternary PEI/PBT/MWCNT PNs rich in PEI varied from 0 to 5 wt.%. The PNs were prepared in a twin-screw extruder-kneader and processed by injection moulding. The electrical conductivity was measured by means of an impedance analyzer and the processability by means of the melt pressure at the output of the extruder. The morphologies were analysed by transmission electron microscopy (TEM). The phase structure of the PNs was characterized by dynamic mechanical analysis (DMA) and differential scanning calorimetry (DSC), and the mechanical properties were measured by means of tensile tests.

The nanostructural analysis conducted by TEM confirmed that the MWCNTs were efficiently dispersed in the new PEI/PBT matrix, mainly in the form of single tubes (Figure 1). The DC conductivity of the PNs increased abruptly in more than 7 decades with the addition of only 1 wt.% MWCNT, indicating the presence of the percolation threshold. The value of percolation critical exponent (t : 1.92) was consistent with that reported by the percolation theory for a three dimensional percolation structure (Figure 2). The processability of PEI clearly improved after PBT-MWCNT master-batch addition, decreasing the pressure at the output end of the extruder by half in the 5%-PN. With respect to the mechanical properties, the Young's modulus increased significantly with increasing MWCNT content. The increase was 27% with respect to the corresponding PEI/PBT blend matrix in the PN with 5wt.% MWCNT. This is due to the large interfacial area-to-dispersed phase volume ratio characteristic of well-dispersed MWCNT PNs. The ductility of the PNs decreased after MWCNT addition, from 60% for pure PEI to around 7%

in the PNs, as a consequence of the stiffness increase caused by the filler presence. Nevertheless, all PNs broke after yielding, indicating their ductile nature.

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References

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Figures

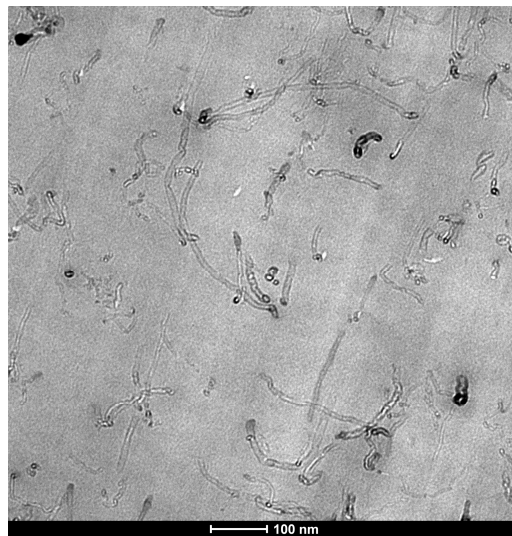


Figure 1. TEM photomicrograph of the PEI based PN with 2% MWCNT.

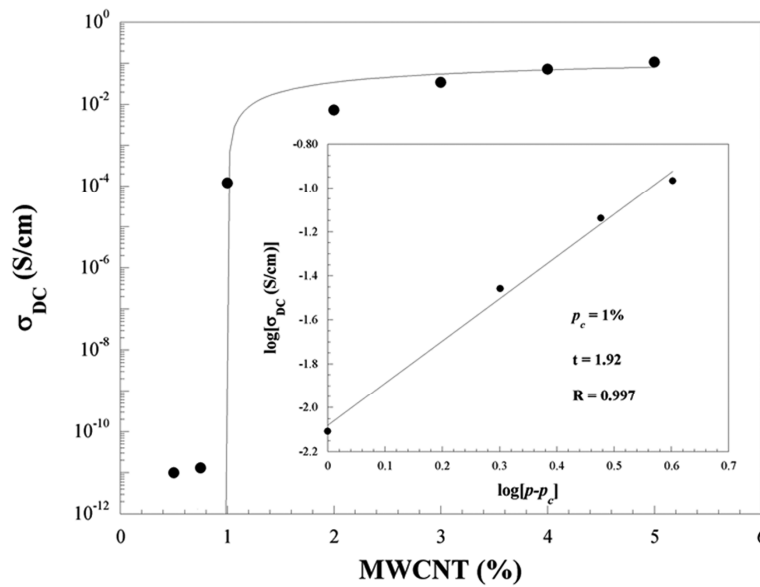


Figure 2. DC electrical conductivity of PEI based PNs vs. MWCNT content at a frequency of 20 Hz. The insert shows $\log(\sigma_{DC})$ versus $\log(\rho-\rho_c)$ and the solid line corresponds to the best fit.