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Structure and mechanical properties of blends of poly(ether imide) and an amorphous polyamide

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Abstract

Biphasic poly(ether imide)/poly(trimethyl hexamethylene terephthalamide) blends were obtained by injection moulding through the full composition range both with and without previous extrusion mixing. The extruded blends showed an improved performance, as the T_gs of the two amorphous phases changed and the changes were larger than those of directly injected blends. The T_g changes indicate the presence of the two components in the two phases of the extruded blends. The consequent low interfacial tension is proposed as the reason for the observed generally fine particle size (typically 0.3 μm). Both characteristics led to mostly ductile materials. The modulus of elasticity and the yield stress were slightly below those predicted by the rule of mixtures. As this was due to a lower orientation in the blends, both properties could improve through a change of the processing parameters. The increase in impact strength over that of pure PEI, and particularly, the sudden processability increase (35% torque decrease) upon a-PA addition, led to compatible blends that, as in the case of the 90/10 composition, could be a polymeric material alternative to unmodified PEI.

Keywords: Poly(ether imide); Amorphous polyamide; Blends; Mechanical properties; Processing

1. Introduction

Blending thermoplastic polymers is one of the most useful ways to develop new polymeric materials. This is because, combining the properties of two polymers in a blend, a performance suitable to the application can be attained. Moreover, combining an expensive polymer with a cheaper one, can be economically advantageous, providing the properties still meet the demands of the application.

Poly(ether imide) (PEI) is a high performance amorphous thermoplastic with high thermal stability ($T_g = 220$ °C) and remarkable modulus of elasticity and tensile strength [1], but is difficult to process. It is used mainly in advanced parts in the electrical and electronics industries, in aircraft applications and in the automotive market. Blends of PEI with other thermoplastics such as poly(ether ether ketone) [2–4], aliphatic–aromatic polyesters [5–9], polyarylate [10,11], poly(phenylene sulfide) and poly(sulfone of bisfenol A) [12], among others, have been studied; as have blends with liquid crystal polymers [13–16].

The poly(trimethyl hexamethylene terephthalamide) (a-PA) is an amorphous, partially aromatic, polyamide

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that shows a high glass transition temperature, about 150 °C, good stiffness and dielectric properties, thermal resistance, dimensional stability and insulating properties [17], as well as resistance to oxygen and other chemical substances. Blends of a-PA with other polyamides [18–22], polyesters [23–25], polycarbonate [26,27], poly(phenylene sulfide) [28], liquid crystal polymers [29–31] and a poly(amino-ether) resin [32] have been studied.

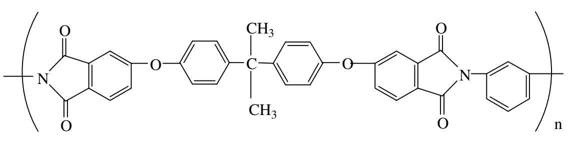
The blends of PEI with polyamide 6,6 (PA 6,6) look attractive as it is expected that the PA 6,6 presence will improve the processability of PEI. Moreover, the polyamides are low cost polymers with high resistance to bases, unlike PEI. On the other hand, the strength and heat resistance of polyamides can be increased remarkably by adding PEI. The PEI/PA 6,6 blends showed two T_gs that shifted towards that of the other component, indicating a slight partial miscibility across all compositions [33]. PEI retarded PA 6,6 crystallization in the blends [34]. However, neither the processability nor the mechanical properties of the blends were reported. Additionally, a patent concerning blends of an amorphous polyamide (hexamethylene diamine–isophthalic acid–terephthalic acid copolymer) and PEI has been registered [35].

In an initial study carried out in our laboratory, the mechanical properties of PEI/PA 6,6 blends showed a negative behaviour. This was attributed to a deficient phase dispersion, which was probably a consequence of the high viscosity difference between the two polymers. Consequently, in spite of the observed improved processability due to the low viscosity of PA 6,6, the possible applications of these blends appeared clearly limited.

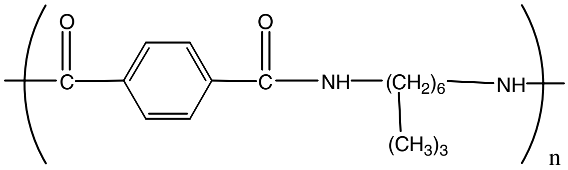
The limitations of the PEI/PA 6,6 blends could be overcome by using a polyamide with higher melt viscosity. Amorphous polyamides have higher viscosities than PA 6,6. For this reason, in the present work, we have studied PEI/a-PA blends across the composition range. The processability, the solid state structure, and the mechanical properties of the blends have been analysed. The effects of the processing method on these structural and performance characteristics have also been investigated.

2. Experimental

The polymers used in this work were a poly(ether imide) (PEI) and an amorphous polyamide (a-PA). The PEI was Ultem 1000 (General Electric). It had the following chemical structure:



Its melt flow index is 8.5 g/10 min, measured at 337 °C and with a 6.7 kg load (ASTM D-1238). The a-PA was Trogamid T-5000 (Creanova GmbH). It had the following chemical structure:



where the pendant methyl groups are in 2,2,4 and 2,4,4 positions in a 1:1 ratio. Its average molecular weights are $M_w = 6.3 \times 10^4$ and $M_n = 2.0 \times 10^4$.

The PEI was dried at 150 °C for 4 h and the a-PA at 120 °C for 16 h. The blends were obtained across the full composition range. The processing of the blends was carried out by two methods: premixing by extrusion followed by injection moulding (PM), and direct blending–injection moulding (DI). Premixing of PM blends was carried out in a co-rotating twin screw extruder-mixer (Collin ZK-25). The screws had a diameter of 25 mm and a L/D ratio of 24. To avoid degradation of the a-PA, and to allow mixing, the barrel temperature was 310 °C for the 90/10 and 80/20 blends, 300 °C for the 70/30 blend, and 290 °C for the rest of the blends. The screw rotation speed was 30 rpm. The rod extrudates obtained were cooled in a water bath, pelletized and dried at 120 °C for 16 h before injection moulding. Injection moulding of both the DI and PM blends was carried out in a Battenfeld BA 230E reciprocating screw injection moulding machine. The screw had a diameter of 18 mm, a L/D ratio of 17.8, compression ratio of 4 and helix angle of 17.8°. The barrel temperature was 300 °C, with the exception of the neat PEI, that was injected at 330 °C. The mould temperature was 21 °C, the injection speed 8.5 cm^3/s and the injection pressure 2250 bar. Tensile (ASTM D-638, type IV) and impact (ASTM D-256) specimens were obtained. To analyze the processability of the blends, some compositions, as well as the neat polymers as a reference, were kneaded in a Brabender batch mixer at 300 °C and 30 rpm until the torque steadied (12 min). The melt viscosity of the PEI and the PEI/a-PA 80/20 blend was measured at 300 °C using a Göttfert Rheograph 2002 capillary extrusion rheometer with a die of 1 mm diameter and L/D ratio of 10.

Calorimetric analyses were performed using a Perkin-Elmer DSC-7 differential scanning calorimeter. The samples were first heated from 30 to 270 °C at 20 °C/min, then cooled at the maximum available speed (approximately 100 °C/min), and heated again under the same conditions. The glass transition temperatures (T_g) were determined in the second heating scan. Dynamic-mechanical analyses (DMA) were performed in a