DEVELOPMENT OF MULTIFUNCTIONAL SELF-REINFORCED COMPOSITES

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1. Introduction

Fibre reinforced polymers are specially designed materials to obtain light high performance structures. In order to apply these materials in the design of structural components, they have to retain their high mechanical performance during a long service life. Their failure is mainly due to delamination, matrix cracking and/or fibre fracture and, its detection is an important issue of scientific and technological current interest. The development of new techniques for damage detection in composite structures represents a key factor to increase their service reliability.

In addition, the growing interest in multifunctional materials is driven by the need of developing new materials and structures, which simultaneously have different structural functions or combined structural and non-structural functions. Therefore, the possibility to develop multifunctional materials able to monitor damage seems to be very attractive.

On the other hand, the environmental impact of the growing use of plastics and composites derived from non-renewable sources makes necessary the development of new combinations of materials with better properties but also with lower environmental impact. As a result, the development of completely recyclable composites is a main topic of research. Currently, there is a great interest in self-reinforced composites based on thermoplastic polymers due to their easy of recycling and the possibility to obtain light structures and components. In these materials, the reinforcement is made of high strength highly oriented fibres or tapes while the matrix is a polymer of the same chemical nature but with a lower melting temperature. Self-reinforced composites compete with traditional composites in different applications depending on their performance/cost ratio. A great number of papers have been published in the literature regarding different aspects of many types of self-reinforced composites [1-4].

In this work, multifunctional nanocomposites based on different thermoplastic polymers (Polypropylene (PP) and Polyethylene Terephtalate (PET)) and carbon nanotubes are developed. These nanocomposites are subsequently used as the matrix and/or the reinforcement in self-reinforced composites. Morphological, thermal and mechanical characterisation is performed on the different matrices, reinforcements and self-reinforced composites. The ability of the obtained materials to monitor damage is also investigated from changes in their electrical behaviour induced by mechanical deformation.

2. Experimental

Films containing 2 wt.% multiwall carbon nanotubes (MWCNT) are obtained by two different methods. Films based on amorphous PET (PETg) are prepared by mechanical stirring of different- viscosity solutions and solvent casting whereas films based on a random PP copolymer (rPP) are obtained by twin extrusion at two different screw speeds (50 and 300 rpm) followed by compression moulding. Mechanical characterisation of the different films is performed through uniaxial tensile tests and their morphology is studied by scanning electron microscopy (SEM).

In addition, nanocomposite fibres based on the different polymers are manufactured by solid state stretching of filaments previously obtained in a twin-screw extruder. Morphological, thermal, structural and mechanical characterisation of the fibres is performed.

Self-reinforced composites are manufactured based on the obtained nanocomposite matrix films and fibres by film stacking followed by compression moulding. Composites mechanical behaviour is studied through uniaxial tensile tests and fracture mechanics experiments under different loading conditions (quasi-static and impact loading conditions).

The potential capability of the obtained nanocomposite films and fibres and self-reinforced composites to monitor damage is also investigated by measuring changes in their electrical behaviour induced by mechanical deformation.

3. Results and discussion

Significantly improved films morphology is obtained from mixing rPP and MWCNTs at high processing speed (300 rpm) or mechanical stirring a high viscosity solution of PETg and MWCNTs. This result is also confirmed from the mechanical behaviour observed in uniaxial tensile tests. While films obtained at high mixing speed or high solution viscosity present stress-strain curves similar to those of neat polymers exhibiting high ductility, films obtained at low processing speed or low viscosity display a much more brittle behaviour derived from the presence of filler aggregates that induce premature failure.

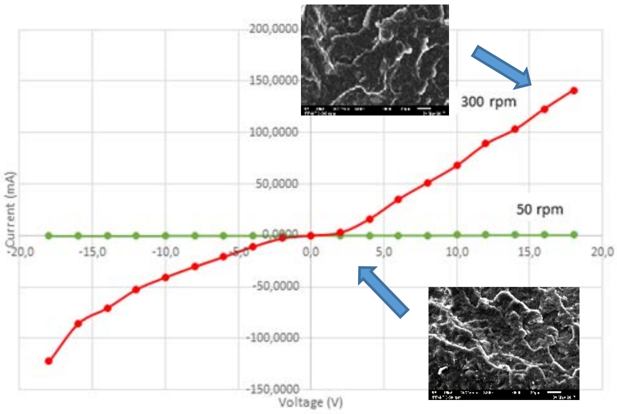

Fig. 1. Current-voltage curves and morphology of rPP nanocomposites obtained at different processing speed.

On the other hand, the electrical resistivity of the different nanocomposite films is significantly lower than that of the polymeric matrices (rPP or PETg), as expected. In addition, a pronounced effect of the extrusion speed on the rPP based films electrical behaviour is observed (Figure 1), confirming the improvement of films morphology promoted by the high shear stresses developed at high speed of mixing. This result is also in agreement with the results of tensile behaviour mentioned before.

Currently, uniaxial tensile tests are being developed on the films up to different subcritical strain levels (before fracture) to determine a correlation between deformation and electrical resistivity and therefore, to analyse the capability of the obtained materials to monitor damage.

Conducting nanocomposite fibres based on PET and PP modified with carbon nanotubes are also being prepared. Based on the nanocomposite films and fibres, self-reinforced composites are being obtained and morphological, thermal and mechanical characterised. Their ability of damage monitoring is also being investigated.

4. Remarks

- An important effect of the processing conditions on the films morphology, tensile behaviour and electrical response is observed for rPP based nanocomposites.
- Currently, self-reinforced composites potential candidates for health-monitoring are being developed based on conductive nanocomposites films and fibres.

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