Graphene/benzoxazine nanocomposites with multifunctional properties

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Benzoxazines are thermosetting resins that have been recently introduced in the aircraft industry as an alternative to bismaleimide resins (BMI) for those applications in which high temperature or FST (fire-smoke-toxicity) performance are desired. BMI are expensive in terms of material and processing conditions (high temperature and long curing time) [1], so much effort has been focused on developing new polymeric matrix as benzoxazine which exhibits excellent properties such as near-zero volumetric change upon curing, low water absorption, high char yield, a low coefficient of thermal expansion, an easy thermal curing by ring opening polymerization and, for some benzoxazines, the glass transition temperature (T_g) might be higher than curing temperature [2].

Since a single-layer graphene was firstly isolated in 2004, a worldwide attention in this material has aroused due to its exceptional mechanical and physical properties [3]. One of the most promising applications of graphene is as nanofiller in polymers in order to provide added value properties to the polymeric matrix [4] due to its exceptional specific modulus and mechanical strength, high electrical and thermal conductivity and good chemical resistance [5].

The current work is focused on developing new multifunctional nanocomposites based on the incorporation of graphene nanoplatelets (GNP) in a benzoxazine in order to achieve a matrix with enhanced mechanical and barrier properties as well as high electrical and thermal conductivity.

A benzoxazine-based resin supplied by Henkel Corporation has been used for this study. Graphene nanoplatelets, with an average flake thickness lower than 2nm, were purchased to Avanzare (Avangraphene-2). Two nanocomposites with a 0.5 and 2 wt.% of graphene nanoplatelets (BzGrAv0.5 and BzGrAv2 respectively) were manufactured by using a three roll calender.

The morphology and the degree of dispersion of GNP in benzoxazine were studied using X-ray diffraction (XRD), where diffraction pattern was obtained for graphene nanoparticles and compared to those from its respective polymer nanocomposites (see Figure 1a). The wide diffraction peak from 10º to 28º is caused by scattering of cured benzoxazine molecules while the tiny shoulder peak found at 26.6º corresponds to the (002) graphitic planes of graphene nanoparticles. The total exfoliation in individual graphene nanolayers is not achieved due to the presence of the graphitic peak in the nanocomposite with a 2 wt.% of GNP.

Thermal stability of nanocomposites was studied using thermogravimetric analysis (TGA) in a dry nitrogen environment and results showed a slight increase in both onset and decomposition temperatures. On the other hand, char formation at 800ºC also increases when the amount of GNP in the sample was higher.

The electrical and thermal conductivity of nanocomposites as a function of the filler content were measured. The thermal conductivity of benzoxazine at room temperature is 0.224 W/mK but with the addition of a 2 wt.% of GNP this value increases by 30% (0.289 W/mK) with regard to the neat resin. On the other hand, the electrical conductivity of benzoxazine dramatically increases with the addition of graphene up to around 10^{-4} S/cm when the amount of GNP in the sample is a 2 wt.%.

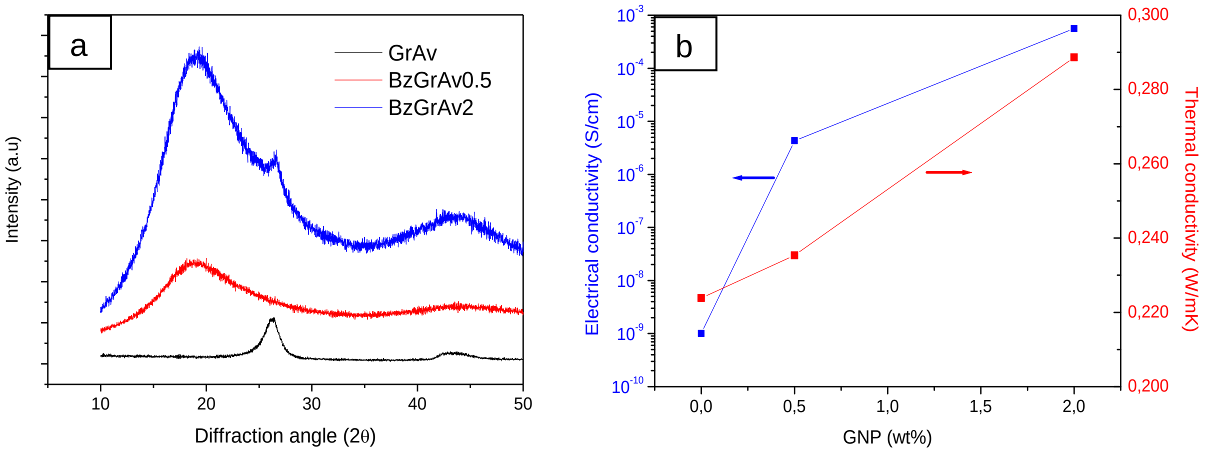

Figure 1: (a) Diffraction patterns of graphene and nanocomposites with a 0.5 and 2 wt.% of GNP; (b) Electrical and thermal conductivity of benzoxazine and its nanocomposites.

Conclusions

Nanocomposites with different amounts of graphene nanoplatelets were manufactured by three roll calender. Although a complete exfoliation of GNP was not reached for the nanocomposite with a 2 wt.% of nanofiller, interesting enhancement in thermal stability as well as thermal and electrical conductivity were achieved.

References

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