Graphene/polymer nanocomposites: thermoset and elastomer matrices

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Abstract

The addition of carbon nanotubes (CNT) to polymer matrices has already been shown to improve their mechanical, electrical and thermal properties. Although significant advances have been made in recent years, these tend to be modest compared to the theoretical performance due to unresolved processing issues. Hence, graphene sheets provide an alternative option to produce functional nanocomposites due to their excellent properties and the natural abundance of its precursor, graphite [1].

The purpose of the studies reported here was to investigate the inclusion of thermally exfoliated graphene (TRG) sheets in a range of polymer systems, both thermoset and elastomers (Figure), and to understand their effects on the curing, morphology and properties [2-10].

The graphene sheets used in these studies were synthesised in our laboratories from the thermal exfoliation and reduction of graphite oxide (GO). GO was produced using natural graphite powder (universal grade, 200-mesh, 99.9995%) according to the Brödie method. This method presents a lower disruption of the Csp^2 graphitic structure than the Hummers method due to a lower oxidation degree, the oxygen contents by elemental analysis are 28% and 48%, respectively. The exfoliation was carried out at 1000 °C under inert atmosphere and did not completely remove the oxygen-containing groups (Figure).

Both epoxy and polyurethane matrices have been studied analysing the effect on the curing kinetics and properties [6-10]. The inclusion of TRG did not did not raise the viscosity of both systems as much as CNT, maintaining the Newtonian behaviour even at 1.5 wt.-% in epoxy. Thus facilitating the processing of the curing materials. Both PU and epoxy resin presented an improved mechanical performance with the addition of TRG. The EMI shielding capabilities of TRG/PU foams were investigated in the X-band frequency region (8–12 GHz) observing an improvement of the specific EMI SE, from 7.6 to 15.15 dB cm^3/g with 0.3 wt.-% TRG.

Silicones and natural rubber [2-5] showed a greater improvement in the mechanical performance than the thermoset matrices, with increments of up to 200 % in the compressive modulus of PDMS foams. TRG was studied as functional filler for the development of electromechanical actuators. We observed a ten-fold increase of the dielectric permittivity at low frequency for composites with 2.0 wt.% of TRG without the introduction of loss mechanisms.

The studies presented describe the successful production of thermoset and elastomer polymer nanocomposites with uniform dispersions of thermally exfoliated graphene. Generally, the inclusion of graphene sheets acted simultaneously as a reinforcing agent without adversely affecting processing. The different systems are especially interesting because of the widespread industrial application.

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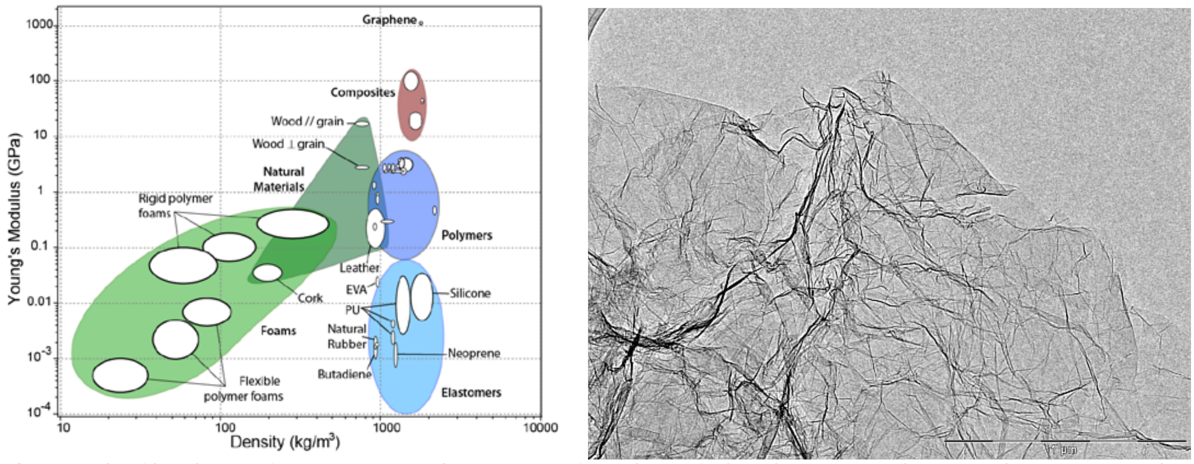

Figure. (Left) Chart of Young's modulus as a function of density comparing graphene properties to polymers and their composites.Graphene density was taken as 2200 kg/m^3. (Right) TEM image of thermally reduced graphene (TRG) showing its characteristic wrinkled structure.