Exfoliated Graphite Reinforced Epoxy/Amine Composite: A Study on Morphological and Electrical Properties

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Although one-dimensional fillers such as carbon nanotubes (CNTs) and carbon nanofibers (CNFs) have been commonly proposed with the aim to transfer their intrinsic excellent physical properties to epoxy matrices [1-3], recently graphite and its derivatives, compete with the aforementioned fillers in many aspects. The potentially high aspect ratio of single graphene sheets combined with the exceptional electrical conductivity may have favorable elements for improving the percolating network when dispersed within polymer matrices in order to obtain electrically conductive composites [4]. However, due do their intrinsic instability graphene sheets tend to roll up and the resulting conductivity may be lower than expected. In order to overcome such drawback in the present study, epoxy resin-based composites reinforced with varying amounts (0.32-6.5wt%) of exfoliated graphite (EG) were fabricated and then morphologically and electrically characterized.

EG particles were prepared through an exfoliation procedure based on intercalation of natural graphite in a strong acidic conditions while the expansion of layer spacing was achieved via heat treatment [4]. Such nanoscale reinforcements have been embedded into an epoxy matrix prepared by mixing a tetrafunctional precursor (TGMDA) with a reactive diluent (BDE). Finally, two-stage curing cycles are adopted for the composites cure.

Exfoliated graphite and composites were morphologically characterized by wide-angle X-ray diffraction (WAXD) reported in Fig.1 and scanning electron microscopy (SEM) shown in Fig.2, respectively. As a result, a percentage of exfoliated graphite of 56% was calculated. The SEM image shows that the EG particulates look like regularly dispersed within the resin. The higher magnifications image as inset of Fig.2 clearly reveals the sheets from the exfoliated graphite with average width of 500 µm. The DC electrical characterization (Fig. 3) reveals a percolation thresholds (EPT) that falls in the range [2-3] wt% and an electrical conductivity of about 0.66 S/m at the highest filler loading (6.5 wt%). The inset of the Fig. 3 allows to evaluate the percolation law parameters such as the critical exponent *t*, which value (i.e. 1.2) is consistent with the type of filler used (2-dimensional) [5]. Finally, an impedance spectroscopy, is carried out in the frequency range [100Hz-1MHz] in terms of impedance modulus/phase (Fig.5 and Fig.6) and dielectric permittivity (Fig. 7) useful to evaluate the effectiveness of EG-loaded composites for electromagnetic interference compatibility (EMC) and their applicability as radar absorbers materials (RAMs).

The influence of the amount of EG filler on the properties of the resulting composites are investigated in order to assist the design of innovative materials with tailored performances.

References

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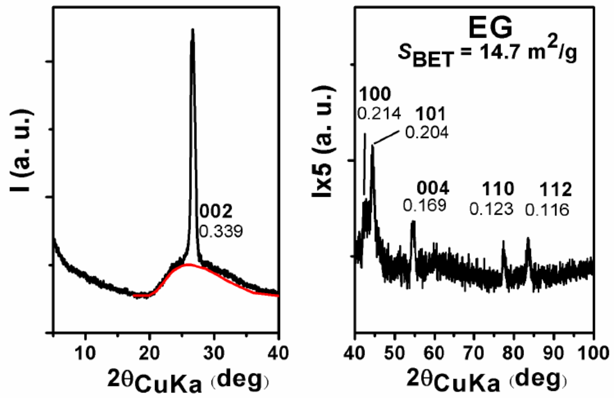

Figure 1: X-Ray pattern of EG.

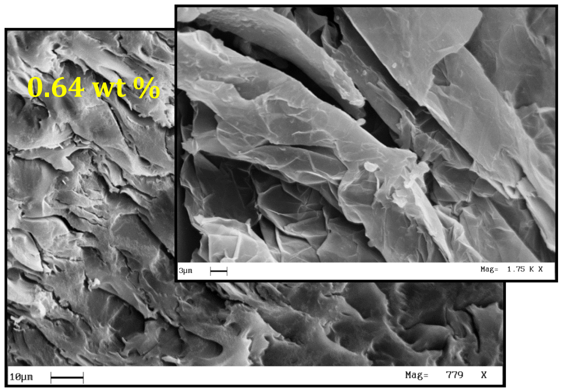

Fig.2: SEM images of the fracture surface of composites filled with 0.64 wt% of exfoliated graphite.

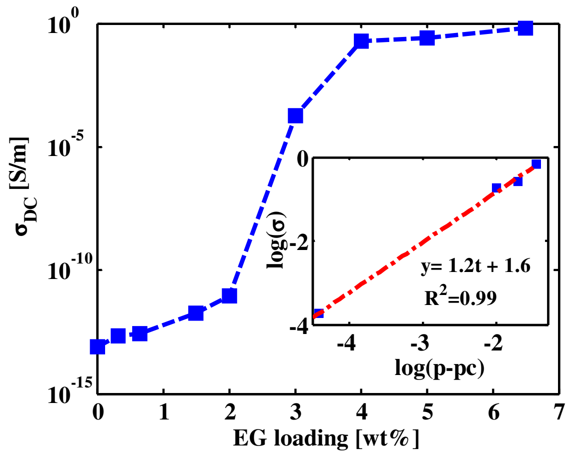

Figure 3: DC volume conductivity of the nanocomposites versus CNFs weight percentage. The inset shows the log-log plot of the electrical conductivity as a function of (p-pc) with a linear fit.

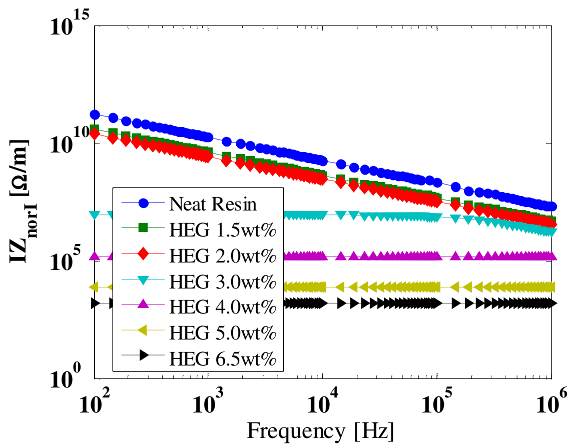

Figure 4: AC behavior of the nanocomposites in the frequency range 100Hz-1MHz. Impedance magnitude normalized with respect to material thickness.

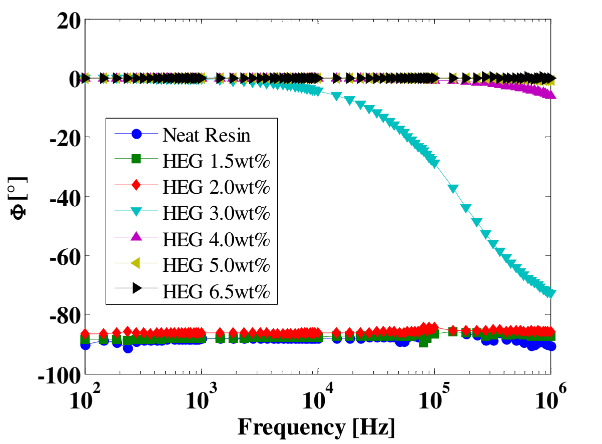

Figure 5: AC behaviour of the nanocomposites in the frequency range 100Hz-1MHz: Phase in degrees.

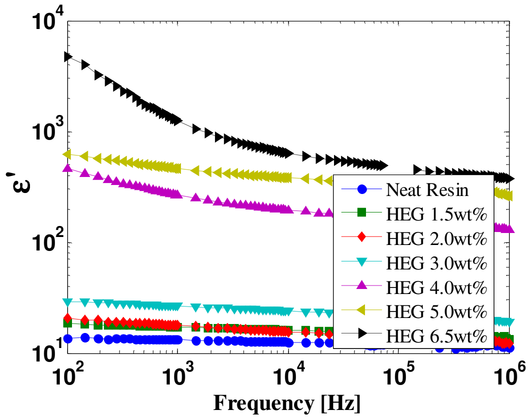

Figure 6: Dielectric permittivity of composites with different EG content as function of frequency