Multifunctional GNP-Epoxy Nanocomposites for Structural Health Monitoring

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Abstract

Graphene is a 2D material that has attracted the interest of many researchers because of its promising properties. Experimental electrical conductivity of non-single layer ranged in the order of ~10^4 S/m makes it especially interesting for its use as filler of non-conductive polymer matrix nanocomposites [1]. Reaching the named percolation threshold, nanocomposite turns conductor and for the nanoreinforcement configuration, electrical resistivity is sensible to strain [2][3]. Another important point is the multifunctionality of resulting material as thermal, mechanical [4][5] and barrier properties can be enhanced [6].

The high aspect ratio of graphene due to a sp^2 hybridization of C atoms provokes usually a preferential orientation of the sheets that can be avoided by making use of a rotary system during curing process. That way, we are capable of obtain nanocomposites with preferential and random orientation what means anisotropic and isotropic materials depending on the manufacturing process.

In this work we propose an overview of mentioned properties for different aspect ratio graphene nanoplatelets (GNPs). Epoxy nanocomposites were processed by mixing GNPs and epoxy monomer by sonication for 45 minutes. After that, mixture was degassed at vacuum under magnetic stirring for 15 minutes at 80 °C. Hardener was then added and the fluid was cured by both of methods at 140 °C for 8 h.

Morphology of nanocomposites was analyzed by TEM, FEGSEM and optical microscopy. Judging from microscopy images and XRD spectra at different parallel sections of the sample, we can conclude that with a normal mold, gravity effect produces a stratification and a preferential in-plane orientation in front of a randomly one in the case of making use of the rotary system. Once we know the reinforcement disposition properties were study in order to achieve multifunctionality.

An ageing process to evaluate barrier properties was carried out for 17 days in an atmospheric chamber under constant humidity of 85 % at 60 °C. Samples employed were those obtained with a preferential orientation parallel to the exposed major surface with a 0.5 wt% of GNPs. Extractions were done at different ageing times to elucidate possible differences in tendencies. All the nanocomposites were flexural tested following ASTM D790. Results confirmed expected differences depending on the aspect ratio of the GNPs. For nanocomposites reinforced with higher aspect ratio GNPs, water absorption was less than for the rest and for this reason mechanical properties are less deteriorated.

Electrical conductivity was measured till reaching percolation threshold. Once percolation threshold was achieved, a monitoring test was taken. Although electrical conductivity (~10^{-5}) is not too high it is enough to monitories materials deformations. Sensibilities to strain of samples with a GNPs content 6, 8 and 10 wt% were calculated and are in the range of 2-3 what means near an order of magnitude greater than that of CNTs.

To summarize we can conclude that the natural preferential orientation of graphene sheets can be easily avoided by making use of a rotary system during the curing stage. This implementation results in a final isotropic nanocomposite that can be desirable for determined applications. A real multifunctionality of these nanocomposites has been corroborated by studying some of the potential intrinsic graphene properties. Properties included in the present work are barrier properties through hydrothermal analysis and electrical conductivity combined with a direct application of Structural Health Monitoring.

References

[1] T. Kuilla, S. Bhadra, D. Yao, N. H. Kim, S. Bose and J. H. Lee, Progress in Polymer Science, **35 no. 11** (2010) 1350–1375.
[2] H. Hosseinzadegan, C. Todd, A. Lal, M. Pandey, M. Levendorf and J. Park, 25th International Conference on Micro Electro Mechanical Systems (MEMS), IEEE (2012) 611–614.
[3] L. Gong, R. J. Young, I. a Kinloch, I. Riaz, R. Jalil, and K. S. Novoselov, ACS nano, **6 no. 3** (2012) 2086–2095.
[4] S. Chatterjee, J. W. Wang, W. S. Kuo, N. H. Tai, C. Salzmann, W. L. Li, R. Hollertz, F. a. Nüesch and B. T. T. Chu, Chemical Physics Letters, **531** (2012) 6–10.
[5] X.-J. Shen, Y. Liu, H.-M. Xiao, Q.-P. Feng, Z.-Z. Yu and S.-Y. Fu, Composites Science and Technology, **72 no. 13** (2012) 1581–1587.
[6] O. Starkova, S. Chandrasekaran, L. a. S. a. Prado, F. Tölle, R. Mülhaupt and K. Schulte, Polymer Degradation and Stability, **98 no. 2** (2013) 519–526.

Figures

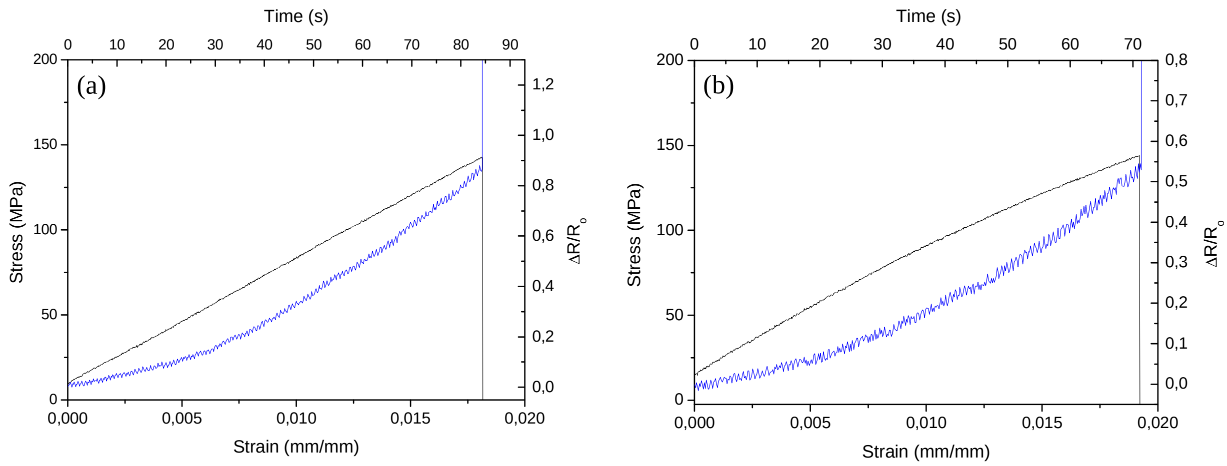

Figure 1. Monitored flexural test of a sample with a (a) 8 wt% GNPs and (b) 10 wt% with electrodes on the face subjected to tensile stress.