Nano Hybrids and Composites
ISSN: 2297-3400, Vol. 29, pp 51-60

Submitted: 2020-04-11
Revised: 2020-05-01
Accepted: 2020-05-04
Online: 2020-06-30

Influence of Different Nano-Structured Fillers on the Performance of Epoxy Nanocomposites

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Keywords: reduced graphene oxide, nano-alumina, epoxy composites, thermal conductivity, electrical properties, strength.

Abstract. Nowadays, multi-functional materials are strongly needed to meet the requirements of next-generation electronic devices. In this work, two different nano-structured fillers, reduced graphene oxide (RGO) and nano-alumina, were chosen to study their effect on the thermal, electrical and mechanical properties of the prepared epoxy composites at different loadings (0.5 to 2 wt%). RGO was firstly prepared and characterized by XRD, Raman spectroscopy and TEM confirming its production. The results revealed that RGO showed excellent adhesion with the polymer. Whilst, alumina aggregated and debonded from the matrix, as confirmed by SEM images. Hence, at only 2 wt%, RGO/epoxy composites exhibited the highest thermal conductivity (0.391 W/m-K), which was 1.96 times higher than the neat epoxy. Whereas, the alumina/epoxy composites showed lower increment at the same loading (0.206 W/m-K). However, at 2 wt% RGO, electrical percolation networks had been formed across the matrix (DC conductivity = 2×10^{-7} S/cm). While, epoxy filled with alumina remained insulative at any loading (~ 10^{-12} S/cm at 100 Hz). Besides, the tensile strength of the composites was improved by 75% and 37% when filled with 0.5 wt% RGO and alumina, respectively. These results are very useful for preparing multi-functional polymeric materials, which are critically required for packaging industries.

Introduction

As a result of the successive miniaturization of electronic components to become more efficient, long-term stable, faster and compatible with complex functions, the amount of generated heat is inconceivable. Proper thermal control is imperative to dissipate the produced heat and to confirm the system's efficiency. Subsequently, packaging or encapsulating the nano- or micro-components with high thermal conductive materials is extremely critical. Polymers rather than metals are the most promising candidate due to their less weight, high electrical insulation, easy processing, and low cost. Nevertheless, polymers are inherently thermal insulators [1].

Epoxy resins are one of the most desired packaging materials owing to their elegant adhesion, mechanical and insulation properties. To tackle the poor thermal properties of epoxies (polymers in general), high thermally conductive but electrically insulative inorganic fillers were embedded successfully into the epoxy and got the proper results [2–7]. Regarding the filler size, it was found that nanofillers could disperse uniformly in the polymer matrix owing to their fabulous surface area. Also, the properties of the matrix could be enhanced at substantial low loadings [8–13]. For example, Han et al. [8] reported 135% and 64% enhancement on the thermal conductivity of epoxy when only 4 wt% of graphene nanoplatelets (GnPs) or boron nitride nanoplatelets were added, respectively. Meng et al. [11] obtained significant improvements in the mechanical, electrical and thermal properties of epoxy adhesives at ultralow contents of GnPs of 0.5 vol%. Thus, nanofillers have confirmed their pioneer roles as reinforcements compared to the microfillers, which produced large dense composites with a poor mechanical performance at high loading [14,15].