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Thermal, electrical and mechanical properties of graphene/nano-alumina/epoxy composites

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HIGHLIGHTS

- Designing an optimum multi-functional polymeric packaging material is a spot challenge.
- Seven different hybrid ratios of RGO/nano-alumina were dispersed by ultrasonication into the epoxy matrix.
- Introducing alumina into the RGO surface effectively interrupted its attraction through the matrix.
- The synergy of RGO/alumina at 6:4 was found to enhance the thermal, insulation and mechanical properties of epoxy.

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ABSTRACT

Graphene-filled epoxy composites have recently attracted much concern in electronic industries. However, graphene can cause sharp diminishment on the electrical resistivity of such composites. To date, electrically insulative alumina nanoparticles are chosen as a secondary filler to isolate the graphene sheets. In the present study, reduced graphene oxide (RGO) was prepared and characterized with FTIR, XRD, Raman spectroscopy, TEM, and AFM analysis. Thereafter, RGO and alumina were dispersed at different hybrid ratios of 10:0, 8:2, 6:4, 5:5, 4:6, 2:8, and 0:10 by ultrasonication into the epoxy matrix at a fixed loading of 1 wt%. Accordingly, the thermal, electrical and mechanical properties of the hybrid epoxy nanocomposites were investigated to achieve the best performance. Based on a decision-making technique, the synergy of RGO and alumina at 6:4 was considered to be the best. At 6:4, the thermal conductivity was enhanced by 23.4%. While, the insulation properties of epoxy composites were retained significantly in contrast to RGO/epoxy composites. Besides, the tensile strength was enhanced by 22.56%. Also, the storage modulus was improved by 4.6% compared to the pure epoxy. It is found that the settling of the alumina nanoparticles on the graphene surface not only inhibits the electron transfer but also eliminates the agglomerations of graphene. This study is important for designing an optimum multi-functional polymeric packaging material.

1. Introduction

Owing to the outstanding insulation, mechanical and cohesion properties of the epoxy resins, they have been vastly used as insulative packaging materials [1–4]. However, their inferior thermal conductivity is considered to be a bottleneck to dissipate the produced heat efficiently and to ensure the electronic system's reliability and stability. To address, the introduction of high thermally conductive fillers into the epoxy polymer is proved to be an effective method to confirm the required thermal management issues [3,5–8]. In the last two decades, a variety of inorganic ceramic materials [5,9–11] have been incorporated into the epoxy polymer to prepare high thermally conductive and electrically insulative epoxy composites. Unfortunately, high filler loading (>50 wt %) was required to achieve the desired properties with a sudden diminishment in the mechanical performance of the composites.

The upcoming down-scaled electronic devices increasingly call for the development of multi-functional materials possessing combined improved properties such as excellent heat dissipation, good mechanical performance, high electrical resistivity [12–14] or optimum electrical conductivity for effective shielding against electromagnetic radiations [15,16], and high resistance to fire [17–19]. This can be achieved by the addition of nanofillers having novel functional characteristics into the polymer matrices. Graphene, a flat two-dimensional single layer with single-atom-thick comprised of carbon atoms packed in a honeycomb

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