J Mater Sci: Mater Electron (2018) 29:3160–3169
DOI 10.1007/s10854-017-8249-8

Preparation and properties of amine functionalized graphene filled epoxy thin film nano composites for electrically conductive adhesive

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Received: 6 September 2017 / Accepted: 9 November 2017 / Published online: 13 November 2017

Abstract The study was carried out to investigate the effect of amine coupling agent of graphene nanopowder (GNP) on the properties of epoxy-based electrically conductive adhesives. Amine-based coupling agent for GNP (m-GNP)/epoxy thin film nanocomposites and GNP/epoxy thin film nanocomposites were fabricated using an ultrasonication and spin-coating techniques. Subsequently, the effect of GNP with different filler loading (0.05–1 vol%) on the tensile properties and electrical properties of the epoxy composites was studied. The GNPs functionalized with amine coupling agent was confirmed with FTIR, AFM and Raman spectroscopy. Generally, it was found that the addition of GNPs decreased the tensile properties of epoxy composites. However, m-GNP/epoxy composites showed higher tensile properties than GNP/epoxy composites at the same filler loading. While, it was found that the percolation threshold of the m-GNP/epoxy composites (0.6 vol%) was much higher than that of the GNP/epoxy (0.1 vol%). Morphological analysis of the GNP fillers by TEM images showed that the average dimensions of m-GNPs layers were far smaller than the average dimensions of GNPs before functionalization. SEM images of the tensile samples cross section confirmed the existence of strong interfacial bonding between m-GNP and the epoxy matrix.

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1 Introduction

Electrically conductive adhesives (ECAs) consist of polymer binder which provides mechanical strength, and conductive fillers, that offer electrical conductivity. ECAs have been identified as an environmentally friendly alternative to traditional tin/lead (Sn/Pb) solders in electronics packaging applications. ECAs also have some potential advantages over the conventional solder techniques which include low temperature processing, finer pitch and simple processing [1]. From these the ECAs are considered as the next generation interconnection materials for electronic packaging [2].

Epoxy is an important class of thermoset polymer and is used as binders in ECAs due to its ease of processing, high tensile strength and modulus, good resistance to heat, chemicals and moisture, dimensional stability (low shrinkage under treatment), and low cost [3]. Graphene with a two-dimensional platelet consisting of carbon atoms arranged in a honeycomb structure, has been the subject of enormous scientific interest due to its fantastic features such as high mobility, optical transparency, room temperature quantum Hall effect, extremely high specific surface area, high mechanical properties with a Young's modulus of 1000 GPa and tensile strength of 130 GPa [4–6]. Its exceptional electrical conductivity of up to 6000 S/m, along with its low viscosity when combined with polymers and non-toxicity, make them excellent candidates as reinforcing and conducting fillers of composites for ECAs [7, 8].

Improvements in tensile and electrical properties by the addition of graphene in epoxy as a polymer matrix have been reported by previous researchers [9, 10]. To achieve optimal enhancement in the mechanical and electrical properties of graphene/epoxy composites, several fundamental challenges should be resolved: (1) uniform dispersion of graphene; (2) the poor adhesion/interaction between the graphene and epoxy as