Research paper

A novel, eco-friendly technique for covalent functionalization of graphene nanoplatelets and the potential of their nanofluids for heat transfer applications

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ABSTRACT

In this study, a facile and eco-friendly covalent functionalization technique is developed to synthesize highly stable graphene nanoplatelets (GNPs) in aqueous media. This technique involves free radical grafting of gallic acid onto the surface of GNPs rather than corrosive inorganic acids. Raman spectroscopy, X-ray photoelectron spectroscopy and transmission electron microscopy are used to confirm the covalent functionalization of GNPs with gallic acid (GAGNPs). The solubility of the GAGNPs in aqueous media is verified using zeta potential and UV–vis spectra measurements. The nanofluid shows significant improvement in thermo-physical properties, indicating its superb potential for various thermal applications.

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1. Introduction

In the last decade, the potential applications of nanoparticle aqueous suspensions with high effective thermal conductivity have gained considerable attention among the scientific community. More recently, there is remarkable enhancement in the thermo-physical and heat transfer properties of carbon-based nanofluids [1–4]. Among various carbon-based nanostructures, graphene nanomaterials are of practical interest because of their favorable thermal, electrical and mechanical properties which can be exploited for various applications [5–10]. Graphene nanoplatelets (GNPs) and nanofluids produced from GNPs are potential candidates for various applications including energy systems. GNPs aqueous suspensions can improve the thermal performance of heat transfer systems by enhancing the thermal conductivity of their conventional working fluids. In this regard, Wei Yu et al. investigated a thermal conductivity of nanofluids containing graphene sheets in ethylene glycol media and reported up to 86% enhancement for 5.0 vol.% graphene dispersion [11]. Moreover, Tessy TheresBoby and Ramaprabh synthesized exfoliated graphene nanofluids with water and ethylene glycol as base fluids then investigated their thermal and electrical conductivities. They reported 14% enhancement in thermal conductivity for volume fraction of 0.056% at 25 °C with deionized water as base fluids [12]. However, the insolubility of graphene in solvents hinders chemical routes using GNPs. In general, GNPs are extremely hydrophobic and prone to aggregation due to strong π–π interactions and therefore, it is difficult to disperse GNPs homogeneously in aqueous or non-aqueous solvents. This greatly limits the applications of GNPs [13]. Hence, several surface modification techniques have been developed to enhance the stability of GNPs in aqueous and organic media via chemical and physical techniques which involve covalent and non-covalent functionalization of graphene [13]. The most common technique used to treat carbon nanomaterials involves processing of these nanomaterials into a mixture of concentrated sulfuric and nitric acids [14] followed by the functionalization process. However, the use of inorganic and strong acids is undesirable because they contribute towards environmental pollution. In addition, these techniques do not only release hazardous and toxic materials to the environment, but they may also have unfavorable effects on the GNP sheets. Hence, there is a need to develop an efficient, easy to use and environmentally friendly technique which will enhance the dispersion of GNPs in aqueous media, and this is an area that has attracted considerable

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