Mechanical properties and corrosion behaviour of functionalised graphene oxide-reinforced epoxy composites

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1. Introduction

Graphene is a monolayer of carbon atoms in which these are arranged into a honeycomb crystal lattice in a two dimensional manner having completely conjugated sp^2-hybridized planer structure [1]. Research in the field of graphene has been one of the profligate developing areas due to its many enthralling properties such as high surface area, superior thermal and electrical conductivity, excellent thermal stability and mechanical strength. All these properties make graphene capable of many applications such as polymer nanocomposite, electronics, ultracapacitor and solar cells etc. Among other valuable applications, graphene extraordinary features make it a potential alternative to currently employed carbon nanotubes as nanofiller in polymer composites. Pristine graphene cannot be used in the larger quantities in polymer matrices due to its poor dispersion in polymers as well as its poor compatibility with polymers. An alternative to pristine graphene is graphene oxide (GO) as it offers better dispersion and compatibility with the polymers due to plenty of oxygen-containing groups (hydroxyl, carbonyl, and epoxide group) present in the faces and edge of graphene sheets [3]. GO has the possibility to be functionalized in order to increase its dispersion and interlocking with polymer matrices [4]. The present work focused to investigate the effect of GO and functionalized GO (FGO) with different filler contents (1, 0.5 and 0.25 wt. %) on the mechanical properties of epoxy composites.

2. Materials and Methods

Epoxy resin used in this work was of gassy nature which was developed by mixing epoxy resin and amine hardener at 1:1 (w/w) [2]. GO was produced from precursor graphite (Asbury Graphite Mills, USA) using improved Hummers' method [5]. GO was covalently functionalized by silane coupling reagent, 3-aminopropyl triethoxysilane (APTS), in accordance with the procedure reported by Ganguli et al. [6] and is labelled as FGO hereafter. Epoxy reinforced composites were developed by solution mixing followed by either roll milling or mechanical mixing. Mechanical properties of composites were determined by tensile testing and flexural testing. Corrosion behaviour of composites as coatings for steel was studied using electrochemical impedance spectroscopy (EIS).

3. Results and Discussion

The comparison of tensile testing of GO and FGO reinforced epoxy (EP) is presented in Fig 1 (a). The composites containing FGO exhibited higher tensile strength values than their GO counterparts over the whole range of filler loadings. An increase in the strength is attributed to the better dispersion of FGO in epoxy resin and good interfacial interaction between filler and matrix. Moreover, composites containing 1 wt. % GO and FGO filler loadings prepared by mechanical mixing exhibit very low tensile strength as compared to their roll milled counterparts. This might be due to the poor dispersion of filler in resin achieved by mechanical mixing

Table 1 shows the flexural properties (Bending modulus, flexural strength and deflection at peak) of neat epoxy and composites containing 1 wt. % GO and FGO prepared from both mechanical mixing and roll milling. Composites prepared by mechanical mixing exhibited superior flexural properties compared to their roll milled counterparts. Fig. 1 (b) shows the Bode plots of 1 wt% GO and 1 wt% FGO epoxy composite coatings developed using film coater on mild steel samples. It can be seen

that FGO coating have much higher impedance (higher corrosion resistance) than GO. This could be due to better dispersion, interfacial bonding between FGO and epoxy matrix which have restricted the movement of the aggressive electrolyte to reach the metal coating interface.

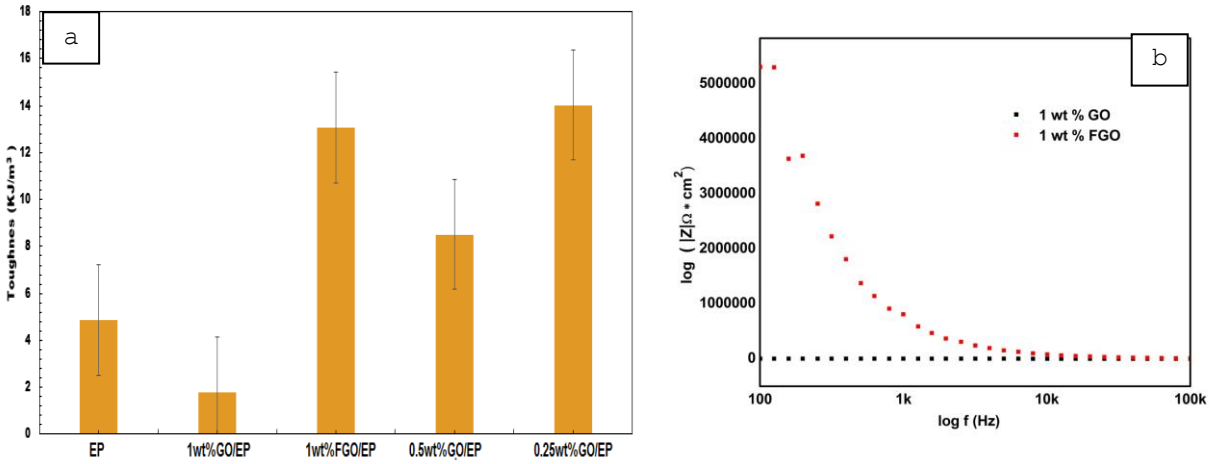

Fig. 1. Relative toughness of EP and composites at different filler content (wt %) of GO and FGO (left) and Bode curve of 1 wt. % GO and 1 wt. % FGO composite coatings in 3.5 % NaCl solution (right).

Table 1 Comparative flexural properties of GO/EP composites.

Sample	Processing Technique	Bending modulus (GPa)	Flexural strength (MPa)
1wt%GO/EP	Roll milling	--	139.70
1wt%FGO/EP	Roll milling	9.40891	229.51
1wt%GO/EP	Mechanical mixing	23.21495	578.75
1wt%FGO/EP	Mechanical mixing	12.35119	179.61

4. Conclusions

The effect of GO (with and without functionalization) at different wt. % was examined through mechanical testing, water absorption and corrosion testing. Composites prepared by roll milling showed better mechanical properties as compared to their mechanical mixed counterparts. The mechanical properties of the composites tend to deteriorate at higher filler loading. At 0.25 wt. % GO loading, the composites showed 182 % increase in the tensile strength. Composites produced by roll milling at 1 wt % GO showed 64 % increase in flexural strength than their FGO counterparts. EIS analysis revealed that FGO based-epoxy composites showed superior corrosion resistance than GO-based composites. .

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