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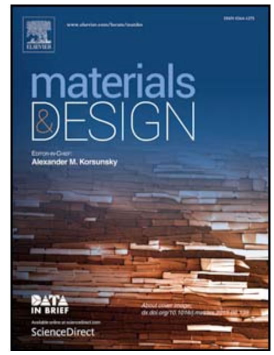

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Raj B. Ladani, Shuying Wu, Anthony J. Kinloch, Kamran Ghorbani, Jin Zhang, Adrian P. Mouritz, Chun H. Wang

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Multifunctional Properties of Epoxy Nanocomposites Reinforced by Aligned Nanoscale Carbon

Raj B. Ladani[1], Shuying Wu[1], Anthony J. Kinloch[2], Kamran Ghorbani[1], Jin Zhang[3]

Adrian P. Mouritz[1], and Chun H. Wang[1*]

[1]Sir Lawrence Wackett Aerospace Research Centre, School of Engineering, RMIT University, GPO Box 2476, Melbourne, VIC 3001, Australia.

[2]Department of Mechanical Engineering, Imperial College London, South Kensington Campus, London SW7 2AZ, U.K.

[3]Institute for Frontier Materials, Deakin University, Geelong Waurn Ponds Campus, VIC 3220, Australia

Abstract

The present paper compares improvements to the fracture energy and electrical conductivity of epoxy nanocomposite materials reinforced by one-dimensional carbon nanofibres (CNFs) or two-dimensional graphene nanoplatelets (GNPs). The effects of the shape, orientation and concentration (i.e. 0.5, 1.0, 1.5 and 2.0 wt%) of nanoscale carbon reinforcements on the property improvements are presented. Alignment of the nano-reinforcements in the epoxy nanocomposites is achieved through the application of an alternating current (AC) electric-field before gelation and curing of the epoxy resin. Alignment of the nano-reinforcements increased the electrical conductivity and simultaneously lowered the percolation threshold necessary to form a conductive network in the nanocomposites. Nano-reinforcement alignment also increased greatly the fracture energy of the epoxy due to a higher fraction of the nano-reinforcement participating in multiple intrinsic (e.g. interfacial debonding and void growth) and extrinsic (e.g. pull-out and bridging) toughening mechanisms. A mechanistic model is presented to quantify the contributions from the different toughening mechanisms induced by CNF and GNP nano-reinforcements on the large improvements in fracture toughness. The model results show that one-dimensional CNFs are more effective than GNPs at increasing the intrinsic toughness of epoxy via void growth, whereas two-dimensional GNPs are more effective than CNFs at improving the extrinsic toughness via crack bridging and pull-out.

Keywords: Nanocomposite, Electrical conductivity, Fracture toughness, Modelling,

1. Introduction

Thermosetting polymers, such as epoxies, are used in a wide range of fibre reinforced composite and coating applications. Despite having many desirable properties, unmodified epoxies typically have low toughness and electrical conductivity. Nanoscale carbon-based reinforcements, such as graphene nanoplatelets (GNPs) [1–3], carbon nanotubes (CNTs) [4–6] and carbon nanofibres (CNFs) [7–10], have been used to increase the toughness and electrical conductivity of commercial epoxies. In addition, carbon-based nano-reinforcements