Materials and Design 32 (2011) 2900–2908

Contents lists available at ScienceDirect

Materials and Design

journal homepage: www.elsevier.com/locate/matdes

Exploring the tensile strain energy absorption of hybrid modified epoxies containing soft particles

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ARTICLE INFO

Article history:
Received 23 July 2010
Accepted 1 December 2010
Available online 4 December 2010

Keywords:
A. Thermoset polymers
E. Mechanical properties
H. Failure analysis

ABSTRACT

In this paper, tensile strain energy absorption of two different hybrid modified epoxies has been systematically investigated. In one system, epoxy has been modified by amine-terminated butadiene acrylonitrile (ATBN) and hollow glass spheres as fine and coarse modifiers, respectively. The other hybrid epoxy has been modified by the combination of ATBN and recycled Tire particles. The results of fracture toughness measurement of blends revealed synergistic toughening for both hybrid systems in some formulations. However, no evidence of synergism is observed in tensile test of hybrid samples. Scanning electron microscope (SEM), transmission optical microscope (TOM) and finite element (FEM) simulation were utilized to study deformation mechanisms of hybrid systems in tensile test. It is found that coarse particles induce stress concentration in hybrid samples. This produces non-uniform strain localized regions which lead to fracture of hybrid samples at lower tensile loading and energy absorption levels.

1. Introduction

Materials energy absorption (EA), which roughly named materials toughness, is an important key concept in designing high performance structures. Some manifestations of EA in structural materials are fracture toughness, total area under the stress–strain curve and impact strength [1–3]. Over three decades, soft modifiers such as hollow spheres, core–shell rubbers, and reactive oligomers. has been applied to enhance the EA capability of brittle thermoset polymers [4–7]. Void growth, cavitation and concomitant matrix plastic deformation are believed to be the dominant mechanisms of rubber modifiers for absorbing energy [8–11]. Furthermore, use of two types of modifiers might produce a hybrid epoxy with higher EA characteristics than that of a single particle modified [12]. As an example, if the toughening mechanisms interact in a positive fashion, a synergism may be achieved in that, for a given volume fraction of modifiers, the fracture toughness of the composition would be greater than additive contributions of the two modifiers separately [12–14]. Synergistic toughening is observed in hybrid epoxy composites containing rubber and hollow glass spheres [15]. Chen and Jan [16] found that epoxy containing large and small rubber particles exhibited toughness greater than that of the additive rule. Bagheri and his coworkers reported synergism in hybrid modified epoxies as a result of plastic zone branching [17] and crack branching [18,19].

From the design viewpoint, there is an important question to be answered: Can hybrid epoxies exhibiting synergistic fracture toughness, show similar trend in other aspects of EA? It is furthermore desirable for the synergism of one mechanical property to not deteriorate the others. To our best knowledge, none of the researchers who reported synergistic fracture toughness in hybrid epoxies have examined other EA manifestations. Pearson and Yee [4] investigated both fracture and tensile behavior of hybrid modified epoxies. However, they did not report synergism in any of the mentioned characteristics. This particular work aims to investigate tensile behavior of hybrid epoxies with capability of synergistic fracture toughness. The tensile EA characteristics of two hybrid epoxies with different ductility are investigated.

2. Experiments

2.1. Materials

Two hybrid systems used in this study are based on Diglycidyl Ether of Bisphenol A (DGEBA) epoxies: The first model system with an epoxy equivalent weight of 170 g/eq (EPON828) is from shell and the curing agent used is piperidine (PIP). The second system

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0261-3069/$ - see front matter © 2011 Published by Elsevier Ltd.
doi:10.1016/j.matdes.2010.12.003