Iran Polym J (2017) 26:913–927
DOI 10.1007/s13726-017-0576-3

ORIGINAL PAPER

Tuning the interlaminar shear strength and thermo-mechanical properties of glass fiber composites by incorporation of (3-mercaptopropyl) trimethoxysilane-functionalized carbon black

Fahd Jamshaid[1] · Adnan Ahmad[1] · Muhammad Adrees[1] · Sadia Sagar Iqbal[1] · Hira Zaheer[1] · Tahir Jamil[1] · Javaid Ahmad[2] · Tousif Hussain[3]

Received: 26 April 2017 / Accepted: 24 October 2017 / Published online: 1 November 2017
© Iran Polymer and Petrochemical Institute 2017

Abstract The incorporation of functionalized nanoscale fillers into traditional glass fiber/unsaturated polyester (GF/UPE) composites provides a more robust mechanical attributes. The current study demonstrates the potential of 3-mercaptopropyl trimethoxysilane (MPTS)-functionalized carbon black (f-CB) for enhancing the thermo-mechanical properties of GF composites. The composites infused with 1, 3 and 5 wt% of pristine and MPTS-functionalized CB were fabricated by hand lay-up and hot press processing. Tensile testing, interlaminar shear strength (ILSS) testing and dynamic mechanical analysis were used to evaluate the performance of nanocomposites. Fourier transform infrared spectroscopy validated the MPTS functionalization of CB. Pristine CB-loaded nanocomposites exhibited marginal improvement in ultimate tensile strength (UTS), ILSS and thermo-mechanical properties. However, with the addition of f-CB, the improvement in all the studied properties was more substantial. The inclusion of 5 wt% f-CB increased the elastic modulus and UTS by 16 and 22%, respectively, whereas the ILSS was enhanced by 36%, in comparison to the neat GF composite. The scanning electron microscope analysis of fractured ILSS samples revealed better fiber-matrix adhesion and compatibility in f-CB-loaded nanocomposites. At the same filler weight percentage, the storage modulus at 25 °C was ~ 19% higher than that of neat composite. The f-CB inclusion resulted in increment of T_g by ~ 13 °C over the T_g of neat GF/UPE composite (~ 109 °C). These improvements were due to the chemical connection of f-CB to the UPE matrix and GF surface. With such improvements in thermal and mechanical properties, these nanocomposites can replace the conventional GF composites with prominent improvements in performance.

Keywords Carbon black · 3-Mercaptopropyl trimethoxysilane · Interlaminar shear strength · Dynamic mechanical analysis · Glass transition temperature

Introduction

Traditional glass fiber reinforced composites (GFRCs) have gained great popularity in the field of metal dominated engineering products. Fueled by the attractive physical properties such as excellent in-plane specific strength and stiffness, ease of fabrication, low thermal expansion, and chemical and corrosion resistance, GFRCs are integrated as structural components in aerospace, transportation, automotive and electronic devices [1–3]. Despite their outstanding in-plane properties, GFRCs exhibit some drawbacks linked to the matrix-dominated out-of-plane properties. They are susceptible to delamination and matrix cracking under bending and impact loading [4]. Special emphasis has been given, therefore, to augment the matrix systems, which involves the addition of nanofillers such as carbon nanofibers (CNFs), carbon nanotubes (CNTs), graphene oxide and nanoclay, etc. [5, 6].

Nanoscale carbon black (CB) is composed of turbostratic aggregation of miniature graphene sheets with fullerene-like defects and possesses an amorphous molecular framework

✉ Fahd Jamshaid
fhdjamshed@gmail.com

1 Department of Polymer Engineering and Technology, University of the Punjab, P.O. Box: 54590, Quaid-e-Azam Campus, Lahore, Pakistan

2 Department of Chemical Engineering, COMSATS Institute of Information Technology, Lahore 54000, Pakistan

3 The Center for Advanced Studies in Physics, Government College University, P.O. Box 54000, Lahore, Pakistan