Research Article

polymers advanced technologies

Received: 12 July 2010, Revised: 20 August 2010, Accepted: 24 August 2010,

(wileyonlinelibrary.com) DOI: 10.1002/pat.1840

Evaluation and modeling of the mechanical properties of graphite nanoplatelets based rubber nanocomposites for pressure sensing applications

Waleed E. Mahmoud[a]*, A. A. Al-Ghamdi[a] and Falleh R. Al-Solamy[b]

Acrylonitrile butadiene rubber (NBR) compounds filled with different concentrations of graphite nanoplatelets were experimentally investigated. The stress–strain curves of the nanocomposites were studied, which suggest good filler–matrix adhesion. The large reinforcement effect of the filler followed the Guth model for non-spherical particles. The effect of graphite nanoplatelets on the cyclic fatigue and hysteresis was also examined. The loading and unloading stress–strain relationships for any cycle were described by applying Ogden's model for rubber nanocomposites. With this model for incompressible materials, expressions may be developed to predict the stress–strain relationship for any given cycle. The dissipated energy increased with graphite nanoplatelets concentrations and decrease with number of cycles. The rate of damage accumulation becomes marginal after first ten cycles. The rate of damage increases as the amount of graphite nanoplatelets increase into the rubber matrix. Copyright © 2011 John Wiley & Sons, Ltd.

Keywords: graphite nanoplatelets; compressive stress–strain; dissipation energy; Ogden model

INTRODUCTION

Graphene, a single-atom-thick sheet of sp^2-bonded carbon atoms, has generated much interest due to its high specific area and novel mechanical, electrical, and thermal properties.[1–7] Recent advances[8–10] in the production of bulk quantities of exfoliated graphene sheets from graphite have enabled the fabrication of graphene–polymer composites. Such composites show tremendous potential for mechanical-property enhancement due to their combination[11–12] of high specific surface area, strong nanofiller–matrix adhesion and the outstanding mechanical properties of the sp^2 carbon bonding network in graphene.

It is generally agreed that the increase in modulus is due to strong interactions between polymer chains and particles, and/or between particles and particles. The study of stress–strain behavior is a crucial clue to elucidate the mechanical properties of any material. The study of elastic energy stored in a body as a result of deformation or distortion under the effect of an applied stress is of great interest for engineers. The expression for the free energy of deformation, W, corresponding to a homogeneous strain is defined by Ogden model, Eq. (7).

The cyclic stress–strain behavior of elastomers has attracted recent attention, particularly when damping ability is considered, since they have good vibration absorption qualities. When samples are loaded under strain control and then unloaded, subsequent extension to the same strain requires a lower force. Further cycling results in continued softening at a progressively slower rate and a steady state may be reached. This softening phenomenon is an important indication of the amount of energy that the material can continue to absorb.[13] This is generally known as the Mullins' effect,[14] especially when considering rubbers. In the case of filled rubber vulcanizates, Harwood et al.[15] suggested that stress softening was mainly caused by changes in the rubber alone, while Bueche[16] and Dannenberg[17] attributed this phenomenon to the fracture of filler chains or weak bonds between the rubber and filler. Therefore, it is important to figure out the characteristics and effects of graphite nanoplatelets in order to understand the material behavior of NBR nanocomposites.

THE OGDEN MODEL FOR ELASTOMERIC MATERIALS

The Ogden model[18] will be used to model the constitutive behavior of an incompressible and isotropic elastomer. In the

---

* Correspondence to: W. E. Mahmoud, Physics department, Faculty of science, King Abdulaziz University, Jeddah, Saudi Arabia.
E-mail: w_e_mahmoud@yahoo.com

a W. E. Mahmoud, A. A. Al-Ghamdi
Physics department, Faculty of science, King Abdulaziz University, Jeddah, Saudi Arabia

b F. R. Al-Solamy
Mathematics department, Faculty of science, Tabuk University, Tabuk, Saudi Arabia

Contract/grant sponsor: Deanship of Scientific Research, Tabuk University, Tabuk, Saudi Arabia; contract/grant number: S1/12/1431.