# Evaluation and Modeling of the Mechanical Behavior of Carbon Nanoparticle/Rubber-Modified Polyethylene Nanocomposites

**Waleed E. Mahmoud, A. A. Al-Ghamdi, F. Al-Marzouki, S. Al-Ameer**

*Physics Department, Faculty of Science, King Abdulaziz University, Jeddah, Saudi Arabia*

Received 7 December 2010; accepted 3 January 2011
DOI 10.1002/app.34107
Published online 6 July 2011 in Wiley Online Library (wileyonlinelibrary.com).

**ABSTRACT:** Recently, the production of polymers loaded with inorganic nanomaterials has been one of the most economical techniques playing a special role in improving the physical and mechanical properties of nanocomposites. Rubbers loaded with different concentrations of carbon nanoparticles (CNPs) were synthesized. The mechanical properties were tested according to standard methods. It was found that the properties of the investigated nanocomposites were improved, depending on the concentration of CNPs in the investigated composite. The optimum concentration was found to be 1.3 vol %. Affine deformation based on the Mooney–Rivilin model was used to visualize the effect of CNPs on the rubber. When polyethylene (PE) was added to rubber/CNPs at the optimum concentration (12.4 vol %), the modulus, tear resistance, and fatigue life were increased, whereas the tensile strength decreased, and the strain at rupture remained almost same. A crosslink model was used to explain the influence of PE on the rubber/CNP nanocomposites.  J Appl Polym Sci 122: 3023–3029, 2011

**Key words:** mechanical properties; nanocomposites; rubber

## INTRODUCTION

In the field of conducting polymeric nanocomposites, one main objective is to minimize the filler concentration because a high concentration of the conductive filler could lead to the deterioration of the mechanical properties of the composite. Different conductive fillers, such as carbon black, graphite powder, and metallic powder, have been explored extensively for composite components, and usually, a higher filler content is loaded to achieve good electrical properties.

Fillers play important roles in modifying the desirable properties of polymers and reducing the cost of their composites. In conventional polymer composites, many inorganic filers with dimensions in the micrometer range, for example, calcium carbonate, glass beads, and talc, have been used extensively to enhance the mechanical properties of polymers. Such properties can indeed be tailored by changing the volume fraction, shape, and size of the filler particles.[1–3] A further improvement of the mechanical properties can be achieved through the use of filler materials with larger aspect ratios, such as short glass fibers.[4–6] The dispersion of fillers with dimensions in the nanometer level having very large aspect ratios and stiffnesses in a polymer matrix could lead to even higher mechanical performances.[7–10] These fillers include layered silicates and carbon nanotubes.[11,12] Rigid inorganic nanoparticles with smaller aspect ratio are also promising reinforcing and/or toughening materials for polymers. The dispersion of nanofillers in polymers is rather poor because of their incompatibility with polymers and large surface-to-volume ratio.[13,14] In this study, we aimed to examine the effect of polyethylene (PE) on the mechanical properties of carbon-nanoparticle (CNP)-loaded rubber composites to reduce the tendency of agglomeration of CNPs and to get rid of the poor dispersion of CNPs in the rubber matrix.

## EXPERIMENTAL

A two-roll mill of length 0.3 m, radius 0.15 m, speed of slow roll 18 rpm, and gear ratio 1.4 was used to prepare such composites. During the mixing process, different ingredients were added as follows: 100 g of rubber was milled for 10 min, after which 2 g of stearic acid, used as coactivator, was added and mixed for 5 min. Zinc oxide (5 g), which used as an activator to enhance the action of organic accelerators, was added and mixed for 7 min. Different contents (0, 1, 2, 3, 4, and 5 g) of CNPs (purchased from Helix

*Correspondence to:* W. E. Mahmoud (w_e_mahmoud@yahoo.com).