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ORIGINAL RESEARCH

Thermo-mechanical properties of high density polyethylene with zinc oxide as a filler

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Abstract
This study investigates the microstructural, thermal, and mechanical behavior of high density polyethylene (HDPE)-based composites prepared using compression molding technique. HDPE was mixed with either micro-size zinc oxide (bulk ZnO) or zinc oxide nanoparticles (nano-ZnO) as fillers' contents at 0, 10, 20, 30, and 40 wt%. The structural, morphological, and thermal properties of the composites were identified using X-ray diffraction (XRD), scanning electron microscope (SEM), Fourier transform infrared spectrophotometer (FTIR), and thermal gravimetric analysis (TGA). The results showed good dispersion and interaction mechanisms between HDPE and the fillers at low weight percentage. The thermal stability of HDPE was enhanced by adding both bulk and nano-ZnO, especially for higher filler loading. Tensile tests at different speeds and Vickers microhardness tests conducted at different indentation loads (0.25–5 N) at $t = 60$ s were performed to realize how the mechanical properties of the composites were influenced. The values of stiffness, ultimate tensile strength, and yield stress increased by increasing the filler loading to 20 wt% of either bulk ZnO or nano-ZnO. The values of ultimate tensile strain and ductility were deteriorated by increasing the filler loading. Nano-ZnO, at 20 wt% content in composite, showed higher mechanical properties than bulk composite, so it has been recommended for a better tensile performance at higher strain rates. Vickers microhardness measurements showed that the tested samples exhibited reverse indentation size effect (RISE) behavior. The obtained results were analyzed using Meyer's law which was a preferred approach for analysis of HDPE/ZnO composite.

Keywords HDPE-based composites · ZnO · Thermal gravimetric analysis · Tensile tests · Vickers microhardness

Introduction

The prompt technological advancements in materials and research disciplines have made ways to enhanced findings and manufacturing new composite materials for various applications. Polymer and metal nanocomposites are considered as top most interesting options that are merits in material engineering due to their properties and advantages such as, flexibility, good functionality, easy processing, durability, large surface-to-volume ratio, and thermo-mechanical properties [1]. The extended fields of applications of polymer nanocomposites, compelled to focus on improving their properties for a better performance, included biomedical applications [2, 3], food processing [4], radiation shielding [5], tissue engineering [6], and purifying water from waste [7, 8]. The nanocomposites can be, consequently, distinguished upon several properties that strongly influence their applications. The thermal, structural, and mechanical properties (Young's modulus, strength, and toughness) of polymers can be upgraded by incorporating nanoparticles as fillers within the polymer matrix to form the nanocomposites. The properties of obtained nanocomposites depend on various parameters including the production technique and nanostructure design [9]. When the filler, mainly at nanometer scale, is merged into the polymer matrix, the composite properties are ameliorated. High density polyethylene (HDPE) is a frequently used polymer due to its superior properties, lightness, and low manufacturing cost. However, its use is constrained due to its limited thermal

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