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Novel flexible and lead-free gamma radiation shielding nanocomposites based on LDPE/SBR blend and $BaWO_4/B_2O_3$ heterostructures

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ABSTRACT

In the present work, flexible lead-free radiation shielding nanocomposite films based on low-density polyethylene (LDPE)/styrene butadiene rubber (SBR) doped with $BaWO_4/B_2O_3$ heterostructures (0, 5, 10, 15, and 20 wt%) were fabricated using the melt blending method. XRD patterns and FTIR spectra revealed the successful preparation of the nanocomposite films and complexation. SEM images and EDX spectra were also used to illustrate the morphology and elemental composition of the prepared nanocomposite films. Furthermore, the research results showed enhanced thermal stability of the nanocomposite films with increased $BaWO_4/B_2O_3$ loading. The mass attenuation coefficient (MAC) values for LDPE/SBR+20 wt% $BaWO_4/B_2O_3$ nanocomposite film improved to 0.07218 cm^2/g compared to 0.06162 cm^2/g for pure LDPE/SBR blend. However, a gradual increase was observed in both parameters of mean free path (MFP) and half value layer (HVL) as energy increases. Moreover, using Phy-X/PSD software, the experimental and theoretical data for MAC were compared. The dependency of the nanocomposite's effective atomic and electron numbers on $BaWO_4/B_2O_3$ content was investigated. The fast neutron removal cross-section (Σ_R) values were increased from 0.1081 to 0.2112 cm^{-1} as the $BaWO_4/B_2O_3$ content increased to 20 wt%. Overall, these nanocomposite films are suitable for radiation shielding applications.

1. Introduction

The ionizing radiation, notably gamma irradiation, is progressively utilized in various applications, such as nuclear reactors, medical diagnostics, academic institutions, and therapy (More et al., 2021). Radiological facilities must be shielded from photon and neutron exposure to avoid radiation-induced cancers in patients and workers in radiation treatment departments. Consequently, the quantity of radiation in these radiation regions should always be limited to a safe level. Also, the most common types of materials used to block radiation are concrete, lead bricks, and sheets. These have limits regarding their mechanical, chemical, optical, and toxic properties (Abdel Maksoud et al., 2021; Sallam et al., 2022).

The lead and concrete, despite their remarkable radiation attenuation capabilities, have not been suggested for radiation shielding. This can be due to the heterogeneous characteristics of lead and moisture change in concretes, resulting in them challenging to utilize especially radiation shielding, in addition to lead risks towards human health and the natural world. Besides difficulties in fabrication of alloys and its corrosion resistance problems; also rocks, including rare earth traces, could be converted to radioactive substances after exposure to high-level radiation doses (Obaid et al., 2018; Nikbin et al., 2019; Levet et al., 2020; Al-Buriahi et al., 2021; Alshahrani et al., 2021; Çelen et al., 2021; Malkapur et al., 2021; Masoud et al., 2022; Tamayo et al., 2022; Arunkumar et al. 2023).

Compared to other types of shielding materials, polymer-metal composite shielding materials offer various benefits, including ease of fabrication, low weight, corrosion resistance, portability, excellent

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