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Evaluation of the structural and radiation transmission parameters of recycled borosilicate waste glass system: An effective material for nuclear shielding

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ABSTRACT

In the present study, the influence of B_2O_3 on the mechanical, physical, and radiation-response characteristics of waste borosilicate glass (BSG) is investigated. Four batches of the glass composite containing 0, 40, 50, and 60 wt % of B_2O_3 each were prepared and labelled as BB0, BB40, BB50, and BB60, respectively, using the popular melt-quench method. Through a series of experimental processes, the glasses' density, hardness, and fracture toughness were measured. The mass attenuation coefficients (MACs), neutron removal cross-sections, and stopping powers of ions in the glasses were estimated using a mixture of Monte Carlo simulations and established theoretical models. By adding boron oxide to the WBSG (BB), a 39.50 % and 38.65 % increase in the density of the glass were observed for BB50 and BB60, respectively. About 9 % improvement was achieved in the hardness of the WBSG reinforced with B_2O_3. The MAC values were between the ranges of 0.0204–5.4610 cm^2/g, 0.193–3.8959 cm^2/g, 0.0189–3.4421 cm^2/g, and 0.0186–3.0347 cm^2/g for BB, BB40, BB50, and BB60, respectively, for gamma photons having energies within 0.015–15 MeV range. Also, the half-value layers for the same gamma photons energy range fell within the ranges of 0.053–14.19, 0.064–12.747, 0.061–10.98, and 0.07–11.226 cm for BB, BB40, BB50, and BB60, respectively. The increase in the boron oxide content in WBSG reduced the effective atomic number of the glass. The present glasses offer cheap and effective alternatives as gamma radiation protection barriers to some recently developed and commercial shielding glasses. The investigated glasses are recommended as cheap, strong, and effective attenuators for gamma, fast neutron, and light and heavy ion radiation.

1. Introduction

Glasses and glass-based materials possess essential attributes that have made them valuable in modern engineering processes, products, scientific investigations, and industries. In fact, glass materials have become invaluable in our everyday lives due to the large number of glass-based products available for assorted applications. Over the years the usefulness of glasses has evolved tremendously due to the versatility in glass preparation chemical structure and properties. In view of the high possibilities in glass chemical structure, many glass systems are yet to be derived and explored for their related attributes and technological relevance. As new glass systems are discovered and characterized new functional materials becomes available for the engineering of advanced tools and equipment relevant in emerging technology. Modern science and technology can thus be said to be contingent upon glass development and characterization to a large extent.

Among major glass formers, B_2O_3 and SiO_2 form quite fascinating glass materials from scientific functionality perspective. Boron is easily bonded due to its strong affinity for oxygen. It always exists in nature in oxygenated forms, especially borates (Smith, 1986). Borate glasses generally have low melting and glass forming temperatures and offers wide range of compositional diversity and properties that fulfil requirements in many fields of applications (Altowyan et al., 2022; Olarinoye et al., 2021; Kurtulus, 2024; Al-Buriahi, 2023). On the other hand, silicate glasses have high processing temperatures of about 1500 °C. This increases their fabrication budget and makes them unsuitable in low

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