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Assessment of gamma-radiation attenuation characteristics of Bi_2O_3–B_2O_3–SiO_2–Na_2O glasses using Geant4 simulation code

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Abstract This work aims to study the radiation shielding properties of Bi_2O_3–B_2O_3–SiO_2–Na_2O glasses (coded as BBS-glasses) using the Geant4 simulation and to determine the effect of the Bi_2O_3 content on the attenuation capability of the glasses. The mass attenuation coefficient (MAC) of BBS-glasses was estimated by the Monte Carlo simulations in Geant4, and the simulated results were validated by XCOM software. The maximum relative difference between the two approaches throughout the considered gamma-ray energies was 1.05, 1.20, 1.40, 1.52, 1.21, and 1.5%, respectively, for BBS-0–BBS-5, which means that MAC estimated through the Geant4 simulation and XCOM are in good agreement; hence, the simulation results are accurate. At each investigated energy, the linear attenuation coefficient value increases with Bi_2O_3 as a result of the higher molecular weight of Bi_2O_3, hence higher electron–photon interactions. The effective atomic number varies from 7.65–9.37, 19.64–66.66, 29.01–73.92, 36.54–76.76, 42.72–78.29, and 47.89–79.23 for BBS-0–BBS-5, respectively. The half value layer for the selected glasses followed the trend: $(HVL)_{BBS\text{-}5} < (HVL)BBS\text{-}4 < (HVL)_{BBS\text{-}3} < (HVL)_{BBS\text{-}2} < (HVL)_{BBS\text{-}1} < (HVL)_{BBS\text{-}0}$. The transmission factor reduces as the thickness of the glasses increases, and the Bi_2O_3 content in the glasses greatly improved their photon shielding and protection ability. The comparison between the mean free path of the selected glasses with other materials revealed that BBS-5 is a better photon shield than BC and RS-360 commercial glass shields.

1 Introduction

For several decades, lead and lead-based materials have been implemented within the materials used to shield against radiation. These radiation shields are defined as any material used to attenuate radiation. Lead has been predominantly used over time because of its excellent absorption ability, high density, and low cost, making it a perfect candidate for shielding purposes. Despite the lead's many advantages, it is toxic to humans and the environment.

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