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Investigation of mechanical properties, photons, neutrons, and charged particles shielding characteristics of $Bi_2O_3/B_2O_3/SiO_2$ glasses

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Abstract

Mechanical properties, uncharged and charged particles shielding capacity of $60Bi_2O_3$-(40-x) B_2O_3-xSiO_2: $x=0$ (S1), 10 (S2), 20 (S3), 30 (S4), and 40 (S5) mol% glasses have been investigated. The enhancement in Young's, shear, and longitudinal elastic moduli and Poisson's ratio of the denser Bi content of the S-glasses was confirmed via bond compression (B–C) and Makishima–Mackenzie (M–M) models. The trend order of the mass attenuation coefficient (MAC) is consistent with that of the mass density as $(S1)_{MAC} < (S2)_{MAC} < (S3)_{MAC} < (S4)_{MAC} < (S5)_{MAC}$. The highest value of the linear attenuation coefficients (LAC) for each of the S-glasses was obtained at photon energy of 15 keV with values of 601, 624, 640, 648, and 661 cm^{-1} for S1–S5, respectively. The increasing trend of the mean free path (MFP) is opposite to that of MAC and LAC with the order: $(S1)_{MFP} > (S2)_{MFP} > (S3)_{MFP} > (S4)_{MFP} > (S5)_{MFP}$. The maximum tenth value thickness (TVT) of the glasses was recorded at 4 MeV with values of 3.93, 3.79, 3.70, 3.67, and 3.60 cm for S1, S2, S3, S4, and S5, respectively. The trend of the effective atomic number (Z_{eff}) directly follows the MAC. Both exposure and energy absorption buildup factors (EBUF and EABUF) were increased with photon energy and depth of penetration except at Bi absorption edges where spikes were seen. Comparing the effective linear attenuation coefficient (ELAC) of the glasses, it is affirmed that S5 has the greatest photon absorption coefficient for all the considered energy and depth. Therefore, the S-glasses are better photon absorber and will perform better in gamma radiation shielding in nuclear facilities compared to commercially available glass shields (RS360 and RS520) and a recently investigated glass matrix (TVM60). In addition, the glass system can thus be used for fast neutron absorber rather than ordinary concrete or water.

Keywords Borate glasses · Mechanical properties · Radiation shielding · MAC · ELAC

1 Introduction

Due to ease of production, low cost, and ability to be shaped into different shapes, glass has over the years become one of the commonest materials with diverse applications in different human societies. Today, glass is used to manufacture everyday household items, optical devices, for aesthetics, and as building material. Glasses are also used for optical coatings, semiconductors, microelectronics, radiation detectors, nuclear waste management, telecommunication, photonics, and many more advanced applications [1–5]. The use of glass for a particular purpose is a function of its chemical composition which in turn dictates its physical, mechanical, and other useful properties. The ease of fine-tuning the chemical composition of glasses have produced novel glasses with more useful applications that have continued to grow. One of the fast-growing areas of application is for

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