Investigation of structural, thermal properties and shielding parameters for multicomponent borate glasses for gamma and neutron radiation shielding applications

ABSTRACT

Multicomponent borate glasses with the chemical composition (60 − x) B2O3–10 Bi2O3–10 Al2O3–10 ZnO–10 Li2O–(x) Dy2O3 or Tb4O7 (x = 0.5 mol%), and (60 − x − y) B2O3–10 Bi2O3–10 Al2O3–10 ZnO–10 Li2O–(x) Dy2O3–(y) Tb4O7 (x = 0.25, 0.5, 0.75, 1.0, 1.5, and 2.0 mol%, y = 0.5 mol%) have been fabricated by a conventional melt-quenching technique and were characterized by X-ray diffraction (XRD), Attenuated Total reflectance-Fourier transform Infrared (ATR-FTIR) spectroscopy, Raman spectroscopy, thermo-gravimetric analysis (TGA), and differential scanning calorimetry (DSC). Also, the radiation shielding parameters such as mass attenuation coefficient (μ/ρ), half value layer (HVL), mean free path (MFP) and exposure buildup factor (EBF) values were explored within the energy range 0.015 MeV–15 MeV using both XCOM and MCNPX code to determine the penetration of gamma and neutron radiations in the prepared glasses. The main BO3, BO4, BiO6, and ZnO4 structural units and AlOAl bonds were confirmed by ATR-FTIR and Raman spectroscopy. Weight loss, and the glass transition (Tg), onset crystallization (Tx), and crystallization (Tc) temperatures were determined from TGA and DSC measurements, respectively. The stability of the glass against crystallization (ΔT) is varied within the temperature range 114–135 °C for the studied glasses. In addition, the shielding parameters like the (μ/ρ) values investigated using both MCNPX Monte Carlo and XCOM software are in good agreement with each other. The (μ/ρ) values calculated using XCOM software were used to evaluate the HVL and MFP in the photon energy range 0.015 MeV–15 MeV. It is found that all the synthesized glasses possess better shielding properties than ordinary concrete, zinc oxide soda lime silica glass and lead zinc phosphate glass indicating the high potentiality of the prepared glasses to be utilized as radiation shielding materials.

Keyword: Multicomponent borate glasses; FTIR; Raman; TGA/DSC; Radiation shielding parameters; Mass attenuation coefficients