Progress in Nuclear Energy 137 (2021) 103763

Contents lists available at ScienceDirect

Progress in Nuclear Energy

journal homepage: www.elsevier.com/locate/pnucene

Dense and environment friendly bismuth barium telluroborate glasses for nuclear protection applications

M.S. Al-Buriahi [a,*], I.O. Olarinoye [b], Sultan Alomairy [c], Imen Kebaili [d], Rumeysa Kaya [a], Halil Arslan [e], Baris T. Tonguc [a]

[a] Department of Physics, Sakarya University, Sakarya, Turkey
[b] Department of Physics, School of Physical Sciences, Federal University of Technology, Minna, Nigeria
[c] Department of Physics, College of Science, Taif University, P.O.Box 11099, Taif, 21944, Saudi Arabia
[d] Department of Physics, Faculty of Science, King Khalid University, P.O. Box 9004, Abha, Saudi Arabia
[e] Electrical and Electronics Engineering, Sakarya University of Applied Sciences, Sakarya, Turkey

ARTICLE INFO

Keywords:
Telluroborate glass
Shielding
Nuclear radiation
Er_2O_3 additive
GEANT4

ABSTRACT

In this paper, four samples of bismuth barium telluroborate glasses in the chemical composition of $20Bi_2O_3 + 30BaO + xEr_2O_3 + (30 - x)B_2O_3 + 20TeO_2$, here x is between 0.05 and 2 mol%) coded as BTBE1, BTBE2, BTBE3, and BTBE4 are reported for potential use in nuclear shielding applications. Geant4 simulations were well designed to obtain the mass attenuation coefficient, μ/ρ for the BTBE1 – BTBE4 specimens at 356 keV–2.51 MeV photon energies. Then, the obtained results are confirmed by using WinXCOM platform. The μ/ρ values were used to assess the nuclear shielding capacity of BTBE1 – BTBE4 specimens in terms of effective atomic number, Z_{eff}, mean free path, MFP, and half-value layer, HVL. Additionally, the buildup factors of BTBE1 – BTBE4 specimens were computed via G-P fitting method at 0.015–15 MeV photon energies and up to 40 mfp (penetration depths). Also, the neutron shielding capacity of the glasses was assessed by calculating the removal cross sections ($\sum_R$). Our results indicate that there is a remarkable enhancement in the gamma shielding features by adding Er_2O_3 content in the BTBE1 – BTBE4 specimens. It is found that BTBE4 and BTBE3 glass specimens have high shielding quality against nuclear radiation. Gamma-rays and fast neutrons shielding parameters of the BTBE1 – BTBE4 specimens are compared with several commercial and traditional shielding materials. These comparisons concluded that the reported glasses are quite useful for radiation protection purposes.

1. Introduction

Ionizing radiation use in various applications including nuclear waste storage and transportation, hospitals, scientific laboratories, and nuclear power plants. Therefore, extensive studies of radiation shielding materials are required for the suggestion and adoption of efficient radiation shield for the preservation of man and the earth. The goals of radiation shielding studies are to minimize the potential for accidental exposures and to ensure that the dose to individuals is as low as possible according to the acceptable levels. In order to achieve these goals a clear understanding of fundamental nature of radiation interaction with matter is required. Therefore, continuous effort is put to explore different types of materials that can be used for the protection of humans, gadgets and the environment from the damaging effects associated with radiation exposure (Ersundu et al., 2018).

Lead (Pb), concrete, and Pb-based materials are extensively utilized in various nuclear facilities as radiation shields. However, there are many drawbacks associated with their usage in the long term (Al-Buriahi et al., 2021a, 2021b; Hegazy et al., 2021; Kurudirek et al., 2018). One of such drawbacks is the poisonous nature of Pb in human system and hence its toxicity in the environment where it forms “lead dust” (Hulbert and Carlson, 2009). To eliminate the usage of lead as shielding material with its toxicity nature, many materials were developed to design low cost, environmentally friendly, and trustworthy radiation shields. Consequently, composites materials such as rocks, polymers, and alloys have been suggested for shielding applications (Elbashir et al., 2019; Al-Buriahi and Tonguc, 2019; Al-Buriahi et al., 2021c, 2021d; Divina et al., 2020).

Heavy metal oxide (HMO) glasses have promising features useful for radiation shielding applications (Al-Buriahi et al., 2020a, 2020b;

* Corresponding author.
E-mail address: mohammed.al-buriahi@ogr.sakarya.edu.tr (M.S. Al-Buriahi).

https://doi.org/10.1016/j.pnucene.2021.103763
Received 1 September 2019; Received in revised form 23 March 2021; Accepted 26 April 2021