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The effects of La_2O_3 addition on mechanical and nuclear shielding properties for zinc borate glasses using Monte Carlo simulation

I.O. Olarinoye[a], Y.S. Rammah[b], Shoroog Alraddadi[c], Chahkrit Sriwunkum[d,**], A.F. Abd El-Rehim[e,f], H.Y. Zahran[e,f], M.S. Al-Buriahi[g,*]

[a] Department of Physics, School of Physical Sciences, Federal University of Technology, Minna, Nigeria
[b] Physics Department, Menoufia University, 32511, Shebin El Koom, Egypt
[c] Department of Physics, Umm AL-Qura University, Makkah, Saudi Arabia
[d] Department of Physics, Ubon Ratchathani University, Ubon Ratchathani, Thailand
[e] Physics Department, Faculty of Science, King Khalid University, P.O. Box 9004, Abha, 61413, Saudi Arabia
[f] Physics Department, Faculty of Education, Ain Shams University, P.O. Box 5101, Heliopolis, 11771, Roxy, Cairo, Egypt
[g] Department of Physics, Sakarya University, Sakarya, Turkey

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ABSTRACT

Effects of La_2O_3 addition on the mechanical and nuclear shielding properties of zinc borate glasses with the form (55-x)ZnO-45B_2O_3-xLa_2O_3: x = 0, 2, 5, and 10 mol% labelled as LZB1-LZB4, respectively were investigated. Bond compression (BC) model and Geant4 simulation code were utilized to achieve these objectives. The value of the bulk modulus (K_{BC}) decreased from 153.116 GPa for LZB1 glass sample to 136.662 GPa for LZB4 glass sample corresponding to an increment of La_2O_3 from 0 to 10 mol%. Longitudinal modulus (L_{BC}) decreased from 280.729 GPa to 249.610 GPa and the Young's modulus (E_{BC}) also decreased from 238.11 GPa to 211.03 GPa for LZB1 to LZB4 glasses. Poisson's ratio (σ_{BC}) increased from 0.240 to 0.243 with the increase of La^{3+} ions in the LZB-glasses. Hardness of LZB-glasses was decreased from 16.578 GPa to 14.572 Gpa. The nuclear radiation shielding properties of the LZBx glasses were explored by utilizing Geant4 Monte Carlo simulations and different theoretical approaches such as ESTAR and XCOM platforms. The obtained values of mass attenuation (MAC) increased in the glasses in the order: LZB1 < LZB2 < LZB3 < LZB4. The maximum values of MAC obtained at energy of 15 keV were 39.157, 40.117, 41.356 and 43.019 cm^2g^{-1} for LZB1, LZB2, LZB3, and LZB4 respectively. Calculated values of fast and thermal neutron macroscopic cross sections varied from 0.1143 to 0.1156 cm^{-1} and 1.9378 to 27,786 cm^{-1} as La_2O_3 varied from 0 to 10 mol% in the glasses. Also, the electron attenuation capacity of the LZBx glasses improved as La_2O_3 content increased. The observed promising properties of LZBx glasses is an indication that they can be useful for several applications including shielding against photons, electrons, and fast/thermal neutrons.

1. Introduction

In fact, the use of ionizing radiation in nuclear power plants, medicine, industry, and space has helped in the development of modern technology. On the other hand, these radiations have harmful effects on human, plant, water, and air in the biota. Ionizing radiation like gamma- and X-rays from natural or artificial sources not only affect the health of workers and patients but can also damage medical instruments after prolonged radiation exposure [1].

Several investigators and engineers have increased their interest in the suggestion, preparation, and production of radiation protection materials to reduce radiation exposure for all environmental components. Previously, concrete, polymers, alloys, and Pb-based composite, have been used as radiation shields [2–9]. Such materials have a lot of beneficial properties such as durability, ease of preparation, and high radiation shielding efficiency [9]. But these conventional materials are opaque and their uses suffer some restrictions in different areas of application. Furthermore, Pb-based materials (e.g. concrete) are now considered toxic and they are completely prevented from use in several applications. For these reasons, several scientists are paying more efforts to search for alternative radiation shield materials.

Currently, glasses are considered as promising candidates in

* Corresponding author.
** Corresponding author.
E-mail addresses: chahkrit.sr.63@ubu.ac.th (C. Sriwunkum), mohammed.al-buriahi@ogr.sakarya.edu.tr (M.S. Al-Buriahi).

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