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Research Article

Radiation Shielding Properties of B_2O_3-Bi_2O_3 Glass

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Abstract:

While technological developments in the modern world offer many opportunities that make human life easier, they also bring various health risks. One of these risks is radiation. Today, radiation is widely used in many areas, such as industry, medicine, agriculture, and nuclear energy production. Although it significantly contributes to social life, exposure can cause various health problems. To protect from the harmful effects of radiation, it is inevitable to research new shielding materials. This study determined the LAC, MAC, HVL, MFP, and Z_{eff} values, which are essential parameters in radiation shielding calculations of the glass system with a chemical content of $65B_2O_3$–$35Bi_2O_3$. The research results showed that LAC and MAC values decreased with increasing energy, HVL and MFP values showed a decreasing trend at high energies, and Z_{eff} values increased.

1. Introduction

The increasing use of radioactive isotopes and nuclear energy in areas such as medical applications, nuclear power plants, space research, industry, and agriculture necessitates protecting personnel against the harmful effects of radiation. For this purpose, it is crucial to develop new protective materials that minimize the biological effects of radiation [1-3]. For this purpose, optimum level shielding materials with high attenuation capacity and suitable physical properties must be developed. Since traditional radiation shielding materials such as lead (Pb) and concrete have various disadvantages, such as toxicity, low mechanical strength, and environmental disadvantages, different research has been carried out on alternative materials based on glass, alloys, and polymers for the attenuation of gamma radiation [4-9]. Individuals working in work environments exposed to radiation must wear appropriate protective clothing to protect themselves from the negative biological effects of ionizing radiation. In this regard, some scientific studies in the literature use different types of textile materials to develop protective clothing with high radiation absorption capacity [10-16].

Bi_2O_3-based heavy metal oxide glasses have a wide range of applications in various fields such as glass ceramic production, thermal and mechanical sensors, substrates for optical and electronic devices, and reflective window systems [17-18]. B_2O_3 is one of the most common glass network formers with a high ability to form amorphous structures [19]. Because Bi^{3}□ ions have low field strength, bismuth oxide by itself does not act as a network former. However, when combined with B_2O_3, it can contribute to glass formation across a fairly broad range of compositions [19-20].
In this study, the radiation shielding parameters of the glass system with the chemical composition $65B_2O_3$–$35Bi_2O_3$ were investigated using Phy-X/PSD software in the energy range from 0.015 to 15 MeV. The density value of $65B_2O_3$–$35Bi_2O_3$ glass is 4.562 (g/cm^3).

2. Material and Methods

Interest in research on designing alternative new shielding materials for radiation protection is increasing daily. The linear attenuation coefficient (LAC) is a fundamental parameter for evaluating a material's radiation shielding performance. This coefficient is calculated based on the Beer-Lambert law (Equation 1).

$$I = I_0 e^{-\mu x} \tag{1}$$

In this equation, I is the count number recorded by the detector when a shielding material is placed between the detector and the radioactive source, I_0 is the count number recorded when no shielding material is present, x is the material thickness, and μ (cm^{-1}) is the linear attenuation coefficient [21-22].

Based on the basic parameter specified in Equation 1, MAC, HVL, MFP, and Z_{eff} values were also calculated through the relations defined in Equations 2-5 [21-24].

$$MAC = \frac{\mu}{\rho} \tag{2}$$

$$HVL = \frac{\ln 2}{\mu} \tag{3}$$

$$MFP = \frac{1}{\mu} \tag{4}$$

$$Z_{eff} = \frac{\sum_i f_i A_i (\frac{\mu}{\rho})_i}{\sum_j f_j \frac{A_j}{Z_j} (\frac{\mu}{\rho})_j} \tag{5}$$

In this study, the glass composition with a chemical composition of $65B_2O_3$–$35Bi_2O_3$ and a density of 4.562 (g/cm^3) was investigated in the calculation of radiation shielding parameters (LAC, MAC, HVL, MFP, Z_{eff}) in the energy range of 0.015 to 15 MeV using the Phy-X/PSD program [25].

3. Results and Discussions

The radiation shielding parameters of the $65B_2O_3$–$35Bi_2O_3$ glass systems synthesized in the study were obtained using Phy-X/PSD software in the energy range of 0.015 to 15 MeV [25]. According to the research findings, the graphs of LAC (μ, cm^{-1}), MAC (μ/ρ, cm^2/g), HVL (cm), MFP (cm), and Z_{eff}, which vary between 0.015 and 15 MeV, are presented in Figures 1-5. When Figure 1 is examined, the linear attenuation coefficient (LAC) values of $65B_2O_3$–$35Bi_2O_3$ glass decrease with increasing photon energy.

This finding suggests that glasses modified with heavy metal oxides are more effective in attenuating low-energy photons, while the probability of high-energy photons passing through the glass matrix increases. The obtained results are also consistent with previous studies in the literature [24, 26-32].

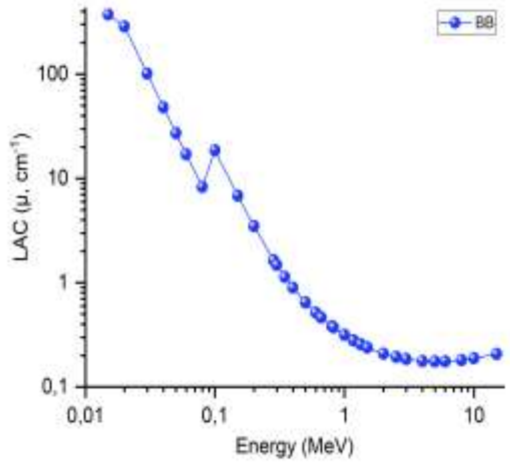

Figure 1. *Change in LAC value depending on energy in B_2O_3-Bi_2O_3 glass sample*

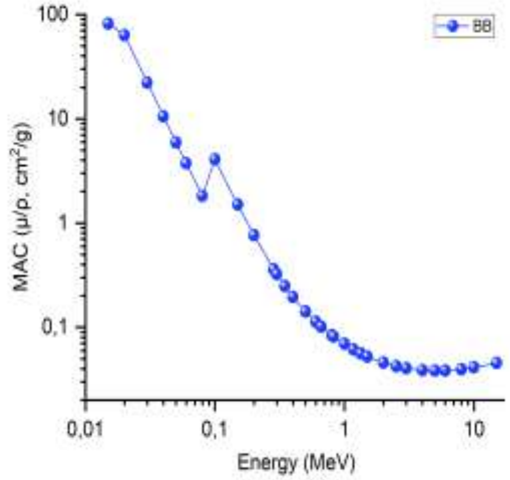

Figure 2. *Change in MAC value depending on energy in B_2O_3-Bi_2O_3 glass sample*

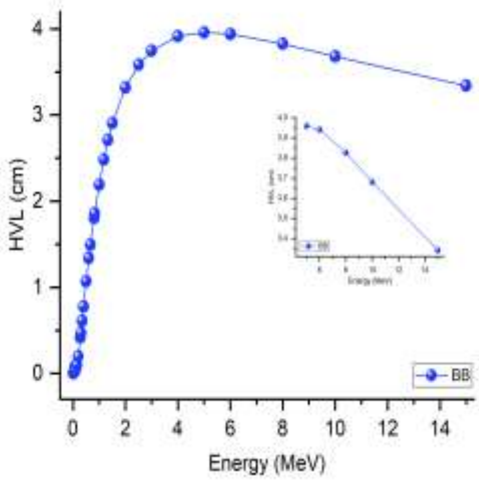

Figure 3. *Change in HVL value depending on energy in B_2O_3-Bi_2O_3 glass sample*

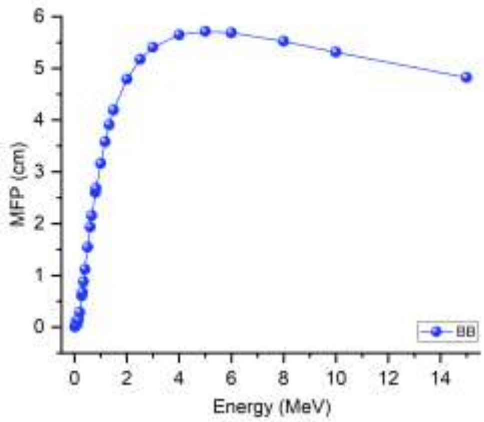

Figure 4. *Change in MFP value depending on energy in B_2O_3-Bi_2O_3 glass sample*

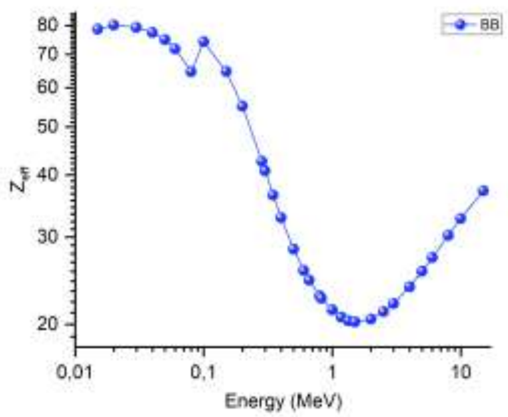

Figure 5. *Change in Z_{eff} value depending on energy in B_2O_3-Bi_2O_3 glass sample*

4. Conclusions

The linear attenuation coefficient (μ, cm^{-1}) is a fundamental parameter in determining the radiation shielding ability of a material. In this study, a glass system with a chemical composition of $65B_2O_3$-$35Bi_2O_3$ was designed. The research results showed that LAC and MAC values decreased with increasing energy, HVL and MFP values showed a decreasing trend at high energies, and Z_{eff} values increased.

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
- **Conflict of interest:** The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

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- **Data availability statement:** The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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