



A comprehensive analysis of the effect of BaO incorporation on Gamma-Ray attenuation characteristics in $\text{SiO}_2\text{-B}_2\text{O}_3\text{-SrO-ZrO}_2$ glass systems

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Abstract

This work presents an analysis of the effect of BaO incorporation on the gamma-ray attenuation properties of systematically evaluated $\text{SiO}_2\text{-B}_2\text{O}_3\text{-SrO-ZrO}_2$ glass matrices. Radiation shielding parameters determined using XCOM and EGS4 calculation codes were compared. There was an increase in glass density from 5.84 g/cm^3 to 6.32 g/cm^3 when the BaO content rose from roughly 10% to 40%. Using sophisticated WinXCom and EGS-4 calculations, the mass attenuation values (μ/ρ) of BaO doped $\text{SiO}_2\text{-B}_2\text{O}_3\text{-SrO-ZrO}_2$ glass systems (abbreviated BaSiBSZ) were found. This study systematically and thoroughly evaluated the effect of BaO integration on the radiation shielding capabilities of the glass system over a wide range of gamma-ray photon energies, specifically between 59.5 keV and 1332 keV. Initially, HVL (half-value layer) and MFP (mean free path) values were derived from the calculated mass attenuation coefficients. The evaluation of several crucial shielding parameters, including RPE, Z_{eff} , Σ_R , and k_γ , came next. The steady reduction of SrO oxide concentration and substitution of BaO in BaSiBSZ glass systems resulted in notable modifications in radiation protection properties. The BaSiBSZ glass systems showed a similar decrease in both HVL and MFP at a constant energy level as the BaO doping concentration was progressively raised. Concurrently, a notable enhancement was noted in RPE, Z_{eff} , Σ_R , and k_γ coefficients. The results demonstrate that higher BaO concentrations greatly enhance the material's radiation-shielding capabilities, enhancing both photon and neutron attenuation and bolstering the overall performance of the glass system.

Keywords BaO doped glasses · Radiation attenuation · Gamma-ray kerma coefficients · EGS4

Introduction

Borosilicate glasses are a type of glass known for their exceptional thermal and chemical stability, as well as low thermal expansion. Composed primarily of silica (SiO_2) and boron trioxide (B_2O_3), these glasses offer high resistance to heat and chemicals, making them ideal for use in various industrial, scientific, and domestic applications. Borosilicate glasses are often used in laboratory equipment, kitchenware, and high-strength glass containers. Additionally, due to their durability and resistance to temperature fluctuations, they are also considered suitable materials for radiation shielding

when appropriately engineered, as seen in some specialized glass compositions [1–4].

Systems of borosilicate glass are particularly well-suited for use in radiation shielding (RSAs), medical technologies, and optics due to their great optical clarity and superior electrical insulation. Their unique combination of properties enhances their utility in environments requiring high performance under thermal stress and chemical exposure, further solidifying their role in advanced technological and industrial fields. Glass materials have a clear edge over other materials when it comes to protecting against gamma radiation. They are ideal for applications where radiation protection and transparency are crucial because of their composition and structural characteristics, which enable efficient gamma ray attenuation [5–9].

An important metric is the mass attenuation coefficient (MAC), which measures a material's capacity to reduce the intensity of an incoming electromagnetic radiation beam as it travels through it. This coefficient shows the likelihood

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that a photon will interact with the material by absorption, scattering, or a mix of the two. The incoming gamma rays' energy levels and the attenuating material's inherent physical and chemical characteristics both have an inherent influence on the MAC. When the energy of the gamma rays increases, MAC usually shows a diminishing trend for a given material. This inverse relationship arises from the fact that higher-energy gamma rays possess a reduced probability of interacting with the atomic structure of the material, resulting in a diminished likelihood of absorption or scattering events. The MAC, as a critical parameter, is essential in quantifying the proportion of incident gamma rays that successfully penetrate the material versus those that are absorbed or scattered, thereby providing insight into the material's radiative shielding properties. In many areas, including industrial radiography, medical imaging, radiation protection, and material characterization, MAC is an important metric. It is valuable because it can quantify the quantity of radiation that is absorbed or transmitted through a certain material. In radiation exposure applications, this measurement is crucial for accurate radiation dose estimations, imaging modality optimization, and safety requirements. The MAC is essential to increasing the efficacy and security of radiation-based technology because it makes accurate predictions of radiation interactions possible. The XCOM algorithm was created by Berger and Hubbell to compute MAC and photon cross sections for atoms, compounds, and mixtures across a wide energy range, from 1 keV to 100 GeV [10]. Gerward et al. improved the software's usability and accessibility by introducing WinXCOM [11], a modified version of the original program. WinXCOM retains the powerful computing power of the original XCOM while offering a more intuitive user interface. This development demonstrates a dedication to facilitating advanced radiation interaction computations for scientists and industry experts. Monte Carlo simulation is a powerful computer technique that employs random sampling to simulate and analyze complex systems or processes when standard analytical solutions are hard or impossible to get. This technique has become a vital tool in a number of fields, including medical physics, nuclear physics, nuclear engineering, radiation safety management, and reactor design. Calculating MAC and other crucial properties has often been done using Monte Carlo techniques, which explain the complex behavior of gamma rays as they interact with different materials. As a result, we now know more about gamma-ray interactions and radiation-related analyses are more accurate [12–15]. The energy deposited in a material as a result of ionizing radiation is referred to in radiation physics as kinetic energy released in materials (KERMA) [16]. Since some energy is transferred to high-energy secondary particles, such as electrons and photons, from interactions with ionizing radiation, kerma typically exceeds the absorbed dosage. The energy is not entirely absorbed at the

contact location since these particles might travel a considerable distance before depositing their energy. This results in a discrepancy between absorbed dosage, which quantifies the real energy deposited, and kerma, which reflects the overall kinetic energy transmit. The absorbed dosage in relation to kerma may be decreased if some energetic particles manage to leave the substance. A significant amount of research has been conducted recently on the computation of kerma coefficients for a variety of composite materials. The need to better understand how ionizing radiation interacts with these materials is the driving force behind this growing interest. Furthermore, the development of more effective radiation shielding methods and the improvement of dosimetry systems depend heavily on these studies [17–20]. This work uses the Monte Carlo EGS4 algorithm and WinXCOM software to theoretically determine the mass attenuation coefficients of BaO-doped $\text{SiO}_2\text{-B}_2\text{O}_3\text{-SrO-ZrO}_2$ glass samples throughout an energy spectrum of 59.5 to 1332 keV. Several shielding parameters, including the HVL, MFP, radiation protection effectiveness (RPE), effective atomic number (Z_{eff}), and gamma kerma coefficients k_{γ} , were computed using the theoretical MAC values obtained from the XCOM and EGS4 calculations. Moreover, the macroscopic effective removal cross sections (ΣR , cm^{-1}) for fast neutrons were calculated from the data. Understanding radiation shielding characteristics and improving protective measures in a variety of applications depend on these factors. The results showed that a higher BaO doping greatly improves the glass sample's radiation shielding capabilities, making it more effective than other glass compositions.

Material and methods

Monte carlo simulation

Nelson and Hirayama's EGS4 (Electron Gamma Showers) algorithm was used in this investigation to carry out the required computations in order to ascertain the gamma attenuation parameters and kerma coefficients [21]. The response of the HPGe detector was simulated using Monte Carlo simulations using EGS4. Using a certified random number generator is crucial since random number creation plays a crucial part in Monte Carlo simulations. In this context, the RANLUX random number generator, which has been demonstrated to yield superior distribution and a longer sequence, was employed in conjunction with the EGS4 code [22]. After dividing the computed area into 241 cells, the form was rotated 360 degrees around the z-axis to produce a cylindrical shape. Figure 1 shows a series of cylindrical circular projections, each with planes called P1, P2, ..., P20 and radii called R1, R2, ..., R11.

of different materials, this idea is very useful in radiation shielding applications. The Z_{eff} values for the studied samples have been determined using the formula found in [28].

$$Z_{eff} = \frac{\sum f_i A_i \left(\frac{\mu}{p}\right)_i}{\sum \frac{f_i A_i}{Z_i} \left(\frac{\mu}{p}\right)_i} \quad (3)$$

where A_i is the atomic weight of the i -th element, f_i is the weight fraction of the i -th element in the material, and Z_i is the i -th element's atomic number [29].

The thickness of a material that reduces half of the radiation entering it is called its half value layer (HVL) [28]: The following formula can be used to get the HVL

$$HVL = \frac{0.693}{LAC} \quad (4)$$

One important measure of the average distance a particle or photon may travel through a material before encountering an interaction, such as absorption, scattering, or transmission, is the mean free path (MFP). The MFP is commonly described as the reciprocal of the linear attenuation coefficient (LAC), which measures the amount of light absorption or scattering that takes place within a material per unit length. Using the following methodology, the MFP values in this study were obtained from the matching LAC values [30]:

$$MFP = \frac{1}{LAC} \quad (5)$$

This study examined the glass samples' radiation protection effectiveness (RPE) parameter. The following formula defines the RPE quantitatively in terms of the incoming and transmitted photon densities: [31]:

$$RPE = \left(1 - \frac{I}{I_0}\right) * 100 \quad (6)$$

Kerma is a quantitative indicator of the energy that is transmitted from ionizing radiation to the material it passes through. Kerma is defined formally as the mass of the absorbing medium divided by the total initial kinetic energy of all charged particles emitted by the incoming radiation. The energy deposited in the target material per unit mass, on the other hand, is represented by the absorbed dosage. This measurement takes into account the charged particles' subsequent interactions with the material, including energy loss mechanisms like ionization and excitation, in addition to the original kinetic energy that was transferred to them. Therefore, while Kerma provides insights into the energy transfer process, the absorbed dose offers a more comprehensive understanding of the energy deposition within the material, highlighting the intricacies of radiation-matter interactions.

In fact, MAC and partial interaction probabilities of various processes can be used to calculate the kerma coefficient (Gy.cm²/photon) for uncharged particles. The formula used to obtain the Kerma coefficient is given below:

$$K = k\phi \left[\frac{\mu_{tr}}{p} \right] \quad (7)$$

In this case, K stands for uncharged radiation with energy E , the mass energy-transfer coefficient of the substance in question, and the kerma coefficient [32]:

$$k_{Ex}(E) = k_D \sum_i w^i \left[(\mu_{tr}/p)_{r,Ex}^i E + \bar{f}_C (\mu_{tr}/p)_{C,Ex}^i E + (\mu_{tr}/p)_{K,Ex}^i (E - 1.022) \right] \quad (8)$$

$$k_t(E) = k_D \sum_i w^i \left[(\mu_{tr}/p)_{r,t}^i E + \bar{f}_C (\mu_{tr}/p)_{C,t}^i E + (\mu_{tr}/p)_{K,t}^i (E - 1.022) \right] \quad (9)$$

Table 1 Chemical composition of barium oxide (BaO) doped glasses (% weight percentage)

Barium oxide (BaO) doped glasses	Density ρ (g/cm ³)	B	O	Si	Sr	Zr	Ba
BaSiBSZ-1	5.84	3.11	38.33	21.04	33.82	3.70	0.00
BaSiBSZ-2	5.96	3.11	37.33	21.04	25.37	3.70	9.45
BaSiBSZ-3	6.08	3.11	36.34	21.04	16.91	3.70	18.90
BaSiBSZ-4	6.20	3.11	35.34	21.04	8.46	3.70	28.35
BaSiBSZ-5	6.32	3.11	34.35	21.04	0.00	3.70	37.80

Table 2 Calculated (EGS4) and Theoretical (XCOM) values of mass attenuation coefficients μ/ρ (cm^2/g), HVL and MFP

Energy	Samples	59.54 keV		122 keV		383 keV		511 keV		662 keV		1274 keV		1332 keV	
		XCOM	EGS4	XCOM	EGS4	XCOM	EGS4	XCOM	EGS4	XCOM	EGS4	XCOM	EGS4	XCOM	EGS4
Mass attenuation coefficients $\mu/\rho(\text{cm}^2/\text{g})$	BaSiBSZ-1	1.401	1.383	0.292	0.293	0.099	0.101	0.085	0.088	0.075	0.076	0.054	0.055	0.053	0.051
	BaSiBSZ-2	1.943	1.965	0.371	0.367	0.102	0.096	0.086	0.086	0.076	0.073	0.054	0.054	0.053	0.052
	BaSiBSZ-3	2.485	2.489	0.449	0.455	0.105	0.097	0.088	0.088	0.076	0.075	0.054	0.056	0.053	0.054
	BaSiBSZ-4	3.028	3.030	0.527	0.530	0.108	0.107	0.089	0.084	0.077	0.073	0.054	0.055	0.053	0.054
	BaSiBSZ-5	3.570	3.543	0.605	0.598	0.111	0.105	0.090	0.093	0.077	0.077	0.054	0.056	0.052	0.055
Half value layer (HVL)	BaSiBSZ-1	0.085	0.086	0.406	0.404	1.200	1.173	1.392	1.338	1.582	1.544	2.195	2.136	2.248	2.314
	BaSiBSZ-2	0.060	0.059	0.314	0.315	1.141	1.202	1.344	1.342	1.540	1.592	2.154	2.134	2.206	2.208
	BaSiBSZ-3	0.046	0.045	0.254	0.250	1.085	1.175	1.299	1.295	1.499	1.519	2.115	2.072	2.166	2.110
	BaSiBSZ-4	0.037	0.036	0.212	0.211	1.034	1.044	1.255	1.321	1.460	1.516	2.077	2.005	2.127	2.037
	BaSiBSZ-5	0.031	0.031	0.181	0.183	0.986	1.038	1.214	1.177	1.423	1.417	2.040	1.961	2.090	1.959
Mean free path (MFP)	BaSiBSZ-1	0.122	0.123	0.586	0.583	1.732	1.692	2.009	1.930	2.283	2.227	3.168	3.082	3.243	3.338
	BaSiBSZ-2	0.086	0.085	0.453	0.455	1.645	1.735	1.939	1.936	2.210	2.192	3.108	3.080	3.182	3.186
	BaSiBSZ-3	0.066	0.066	0.366	0.361	1.566	1.695	1.873	1.868	2.163	2.182	3.051	2.989	3.125	3.045
	BaSiBSZ-4	0.053	0.053	0.305	0.304	1.491	1.506	1.810	1.908	2.106	2.187	2.996	2.893	3.069	2.936
	BaSiBSZ-5	0.044	0.044	0.261	0.264	1.423	1.498	1.751	1.696	2.053	2.045	2.943	2.829	3.016	2.826

The photon kerma coefficients can be found using a variety of techniques described in earlier research [18, 33, 34]:

A key metric in nuclear reactor analysis and neutron transport theory is the fast neutron macroscopic cross-section Σ_R (cm^{-1}), which captures the interaction probability per unit distance traveled by fast neutrons in a material medium.

The following relationship is used to get the Σ_R value for neutron shielding materials.

$$\Sigma_R / \rho = \sum_i W_i (\Sigma_R / \rho)_i \quad (10)$$

and

$$\Sigma_R = \sum_i p_i (\Sigma_R / \rho)_i \quad (11)$$

where the partial density of the i th element is represented by ρ_i (g/cm^3) and the fast neutron removal cross section by Σ_R/ρ (cm^2/g) [28, 35–37]: The following formula can be used to determine the partial density of the i -th element, represented as (ρ_i):

$$p_i = p \times w_i \quad (12)$$

Here, w_i stands for the weight fraction of the i th element, and ρ for the sample's density (g/cm^3) [28]:

Results and discussion

Table 1 lists the physicochemical characteristics of glasses doped with barium oxide (BaO). The MFP, HVL, and MAC μ/ρ ($\text{cm}^2 \text{g}^{-1}$) for samples at different energies of 59.5, 122,

Fig. 2 The dependency of the half-value layer (HVL) on photon energy in BaO-doped SiO_2 - B_2O_3 - SrO - ZrO_2 glass systems

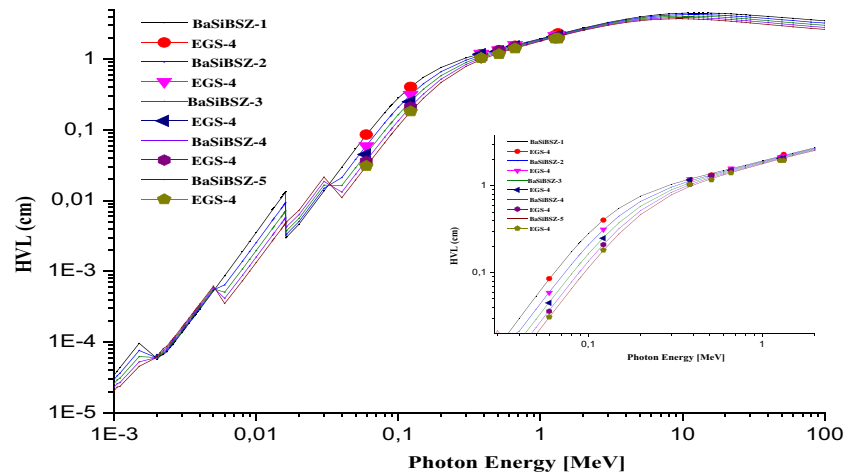


Fig. 3 The dependency of the mean free path (MFP) on photon energy in BaO-doped SiO_2 - B_2O_3 - SrO - ZrO_2 glass systems

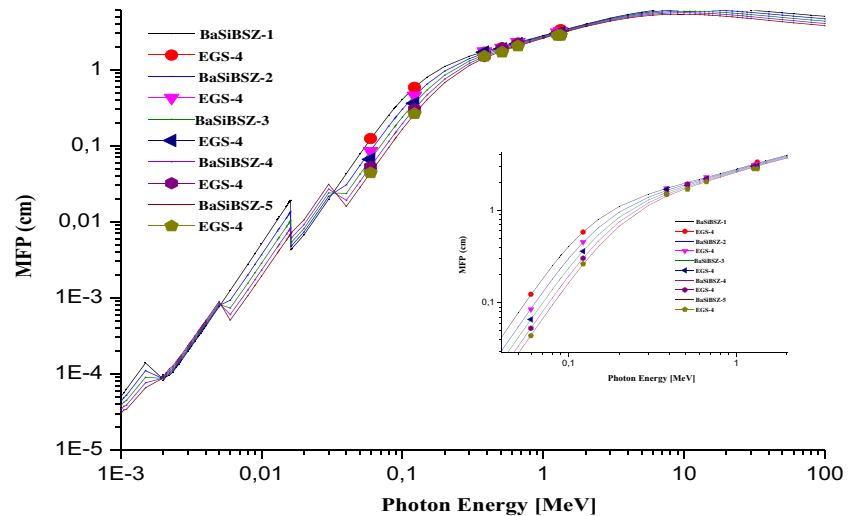


Table 3 Calculated (EGS4) and Theoretical (XCOM) values of effective atomic number (Z_{eff}) values, Radiation protection efficiency (%) and kerma coefficients k (in pGy.cm²/photon)

Energy	59.54 keV		122 keV		383 keV		511 keV		662 keV		1274 keV		1332 keV	
	XCOM	EGS4	XCOM	EGS4	XCOM	EGS4	XCOM	EGS4	XCOM	EGS4	XCOM	EGS4	XCOM	EGS4
Radiation protection efficiency (%)														
Samples														
BaSiBSZ-1	99.97	99.96	81.87	81.86	43.86	44.62	39.21	40.42	35.47	36.17	27.07	27.70	26.53	25.88
BaSiBSZ-2	99.99	99.98	89.01	88.34	45.53	43.14	40.28	39.70	36.24	34.71	27.51	27.25	26.95	26.47
BaSiBSZ-3	100	100	93.47	93.01	47.20	43.37	41.35	40.21	37.02	35.64	27.94	28.53	27.38	27.76
BaSiBSZ-4	100	100	96.19	95.46	48.85	46.48	42.43	38.98	37.79	34.98	28.37	27.77	27.80	27.41
BaSiBSZ-5	100	100	97.82	96.95	50.48	46.02	43.50	41.96	38.56	36.35	28.80	27.85	28.22	27.88
Effective atomic number (Z_{eff})														
BaSiBSZ-1	29.26	29.35	18.97	19.22	12.85	12.80	12.59	12.34	12.47	12.05	12.35	12.19	12.35	12.59
BaSiBSZ-2	35.33	34.90	22.76	23.01	13.46	14.30	13.03	13.18	12.82	12.91	12.61	12.47	12.61	12.44
BaSiBSZ-3	40.01	39.95	26.17	25.83	14.09	15.26	13.48	13.45	13.19	13.36	12.89	12.43	12.89	12.65
BaSiBSZ-4	43.72	43.69	29.25	29.09	14.75	14.89	13.96	13.99	13.57	13.61	13.18	12.94	13.18	12.93
BaSiBSZ-5	46.74	47.10	32.05	32.43	15.42	16.30	14.45	14.08	13.97	13.92	13.48	13.01	13.48	13.23
Kerma coefficients k (in pGy.cm ² /photon)														
BaSiBSZ-1	11.39	11.25	3.172	3.178	2.014	2.058	2.492	2.574	3.085	3.126	5.208	5.320	5.403	5.220
BaSiBSZ-2	16.46	16.64	4.640	4.604	2.203	2.075	2.606	2.591	3.156	3.050	5.219	5.242	5.411	5.338
BaSiBSZ-3	21.52	21.55	6.125	6.208	2.393	2.210	2.719	2.726	3.226	3.182	5.230	5.455	5.420	5.561
BaSiBSZ-4	26.59	26.61	7.602	7.643	2.582	2.555	2.833	2.800	3.297	3.144	5.241	5.377	5.428	5.579
BaSiBSZ-5	31.65	31.41	9.078	8.968	2.771	2.617	2.947	3.034	3.367	3.364	5.252	5.494	5.437	5.701

Fig. 4 The variation of effective atomic numbers Z_{eff} of BaO-doped $\text{SiO}_2\text{-B}_2\text{O}_3\text{-SrO-ZrO}_2$ glass systems versus the photon energy

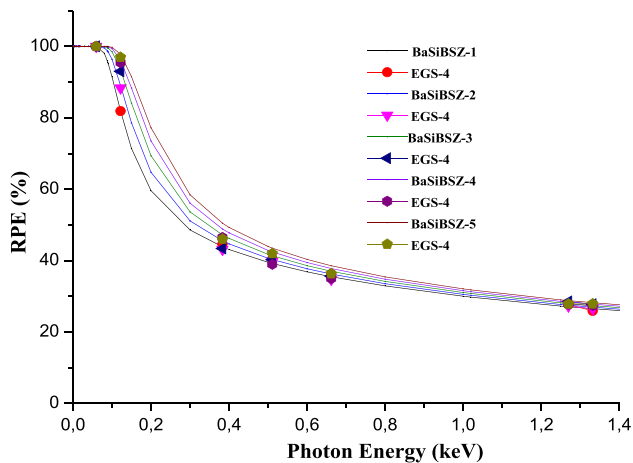
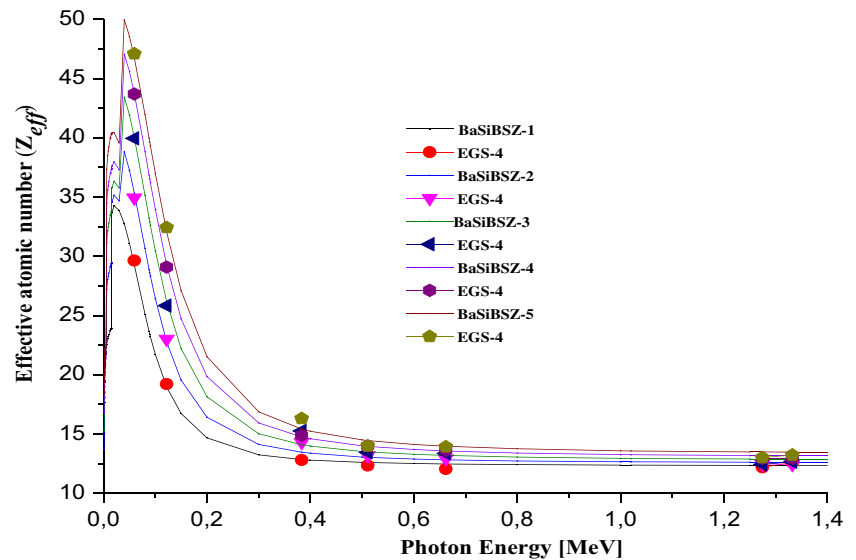


Fig. 5 The variation of radiation protection efficiency (RPE) of BaO-doped $\text{SiO}_2\text{-B}_2\text{O}_3\text{-SrO-ZrO}_2$ glass systems versus the photon energy

383, 662, and 1332 keV are displayed in Table 2. Figures 2 and 3, respectively, display photon energy dependent HVL and MFP for BaO-doped $\text{SiO}_2\text{-B}_2\text{O}_3\text{-SrO-ZrO}_2$ glass samples. Analysis of the presented figures reveals that with an incremental increase in BaO doping within the BaSiBSZ glass systems, there is a concomitant reduction in both HVL and MFP at a constant energy level. This trend suggests that enhanced BaO concentrations significantly influence the attenuation characteristics of the glass matrix, leading to an increased likelihood of photon interactions. Consequently, the modifications in these parameters underscore

the potential of BaO-doped BaSiBSZ glasses in applications requiring effective radiation shielding and attenuation properties. Table 3 displays the Z_{eff} , RPE, and kerma k (in $\text{pGy} \cdot \text{cm}^2/\text{photon}$) as calculated EGS4 and WinXCOM values. Figure 4 illustrates how Z_{eff} varies with photon energy in BaO-doped BaSiBSZ glasses. The Z_{eff} is directly impacted by the amounts of each element inside the glass matrix since each element has a distinct atomic number. Figure 5 shows the RPE changes with photon energy for the glass samples that are being studied. These glasses' performance in applications like radiation shielding or optical systems is influenced by variations in their composition, which results in variations in RPE values. Furthermore, the different alloys' ΣR were computed and shown in Fig. 6. As shown in Fig. 6, BaSiBSZ-5 had the largest ΣR (cm^{-1}) value, whereas BaSiBSZ-1 had the lowest. Thus, the BaSiBSZ-5 glass sample exhibits an increased total interaction cross-section (ΣR) as a result of its greater density relative to the other samples. As a result, it is the best material for absorbing neutrons and provides better protection from gamma radiation.

Figure 7. displays the BaO-doped $\text{SiO}_2\text{-B}_2\text{O}_3\text{-SrO-ZrO}_2$ glass systems' gamma kerma coefficients with photon energy. At different energy levels, the dominating gamma-ray interaction mechanisms have a considerable impact on the kerma. In the low-energy domain, where the photoelectric effect predominates, the kerma values exhibit a notable increase with increasing atomic number (Z). This is because the photoelectric effect transfers nearly all photon energy

Fig. 6 Fast neutron removal cross sections of the given glass samples

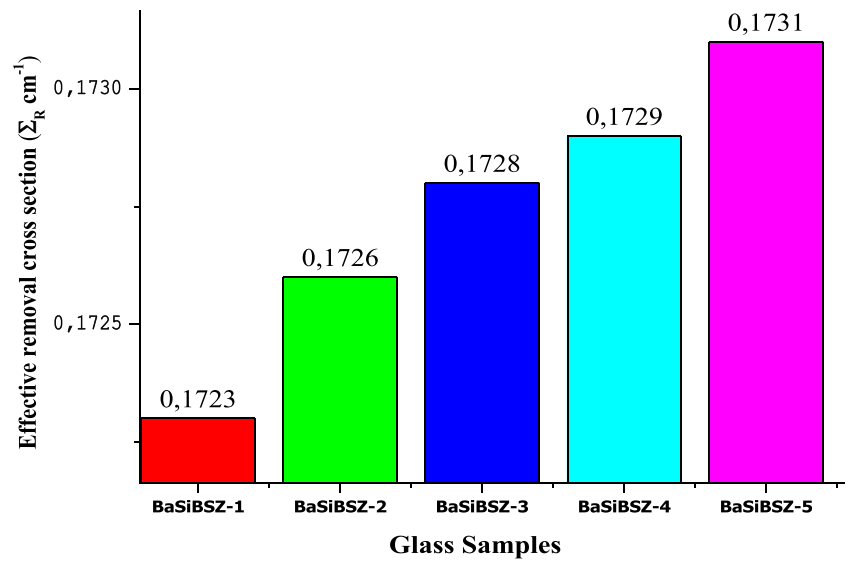
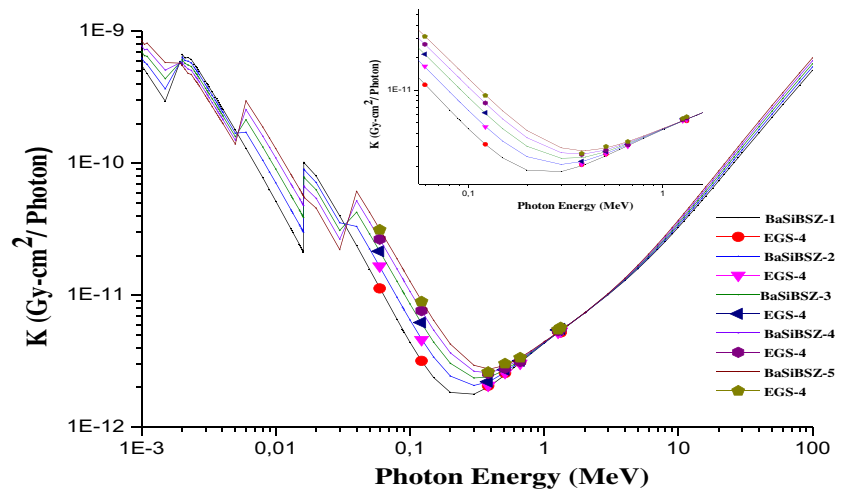


Fig. 7 The gamma kerma coefficients of BaO-doped SiO₂-B₂O₃-SrO-ZrO₂ glass systems as a function of photon energy



to electrons while imparting nearly little kinetic energy to them, especially in materials with higher Z values. Moreover, Compton scattering contributes to this increase by allowing partial energy transfer to the medium since it is almost elastic at low photon energies. Higher photon energies lead to higher kerma coefficients because Compton scattering and pair formation, which both require greater energy transfers, become more dominant. The underlying reason for the variations in kerma coefficients as a function of energy is the complex interaction between the Z-dependence of the mass attenuation coefficient and the dominance of various gamma-ray interaction processes at different energy levels. For equivalent photon energies, the kerma coefficients of SiO₂-B₂O₃-SrO-ZrO₂ glass systems clearly show an upward trend as the BaO content increases. The relative dominance of several mechanisms of photon interaction, such as the photoelectric effect, Compton scattering,

and pair production, determines the characteristics of kerma coefficient curves with respect to gamma-ray energy. The photon energy and the atomic number of the material being absorbed determine how much of each of these interaction mechanisms contributes. Compton scattering and pair creation become more dominant in the intermediate energy range as photon energy rises, whereas the photoelectric effect falls proportionately. The kerma coefficient significantly drops as a result of this change.

Conclusion

The radiation shielding properties of BaO-doped SiO₂-B₂O₃-SrO-ZrO₂ glass samples were investigated in this work throughout a gamma energy range of 59.5 to 1332 keV. Based on the MAC values, it was utilized to compute

a number of shielding parameters, such as the MFP, HVL, RPE, Zeff, and kerma. Furthermore, the various glasses ΣR were computed. EGS4 was used to analyze the MAC, MFP, HVL, RPE, Zeff and kerma coefficients for the glass samples under study at gamma ray energy of 59.5, 122, 383, 511, 662, 1274, and 1332 keV. To ensure safety, maximize material performance, and further research in radiation shielding technologies, it is crucial to calculate radiation protection parameters for glass samples.

Mass attenuation coefficients are shown to significantly decrease with increasing BaO concentration in $\text{SiO}_2\text{-B}_2\text{O}_3\text{-SrO-ZrO}_2$ glasses, particularly up to the first 500 keV. At a fixed energy level, BaO-doped glass samples show a drop in MFP and HVL. The gamma-ray kerma coefficients, Zeff and RPE all significantly rise in tandem with this. The results demonstrated that the BaSiBSZ-5 glass sample had superior radiation shielding qualities when compared to the other glass samples. It is therefore recognized that the recently developed glasses are particularly helpful for radiation shielding applications in the industrial, medicinal, and nuclear fields. To ensure safety, maximize material performance, and further research in radiation shielding technologies, it is crucial to calculate radiation protection parameters for glass samples. This effort will contribute to the development of novel, safe, and efficient glass systems that are especially made for situations where radiation exposure is a major issue.

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Data availability All relevant data generated or analysed during this study are included in this manuscript. The data used in this article can be available upon reasonable request from the corresponding author. All data within the manuscript. No more additional data is available.

Declarations

Ethical approval Not applicable.

Competing interests The authors declare no competing interests.

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