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Research Article

The Effect of Lead Oxide on the Change in Gamma Ray Protection Parameters of Bismuth Oxide

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Abstract

The aim of this study is to investigate the gamma ray radiation absorption properties of bismuth oxide (Bi_2O_3), and determine the effect of lead oxide (PbO) additive in the shielding of Bi_2O_3. For this reason, the radiation absorption parameters such as mass attenuation coefficient (MAC), linear attenuation coefficient (LAC), half value layer (HVL), tenth value layer (TVL) and mean free path (mfp) were calculated theoretically for the Bi_2O_3, PbO, and 50% Bi_2O_3-50%PbO. The all parameters results were obtained by using the GATE/Geant4 (Geant4 Application for Tomographic Emission) simulation code in energy range 511 keV, 662 keV, 1173 keV, 1274 keV, and 1332 keV. Also, the gamma ray protection parameters were calculated by using the XCOM program in the energy range from 1 keV to 1 GeV. Thus, the simulated the GATE/Geant4 results were tested for correctness using the XCOM program. On the other hand, theoretically were calculated values of all parameters of the shielding materials were compared with each other. These results indicate that the GATE/Geant4 results were in good agreement with the XCOM results.

Keywords: XCOM, GATE, Bi_2O_3, PbO, Radiation Shielding

Bizmut Oksit'in Gama Işını Koruma Parametrelerindeki Değişime Kurşun Oksit Etkisi

Öz

Bu çalışmanın amacı, bizmut oksidin (Bi_2O_3) gama ışını radyasyonu absorpsiyon özelliklerini araştırmak ve kurşun oksit (PbO) katkısının Bi_2O_3'ün kalkanlanmasındaki etkisini belirlemektir. Bu nedenle Bi_2O_3 için kütle zayıflama katsayısı (MAC), doğrusal zayıflama katsayısı (LAC), yarı değer katmanı (HVL), onuncu değer katmanı (TVL) ve ortalama serbest yol (mfp) gibi radyasyon absorpsiyon parametreleri teorik olarak hesaplanmıştır. , PbO ve %50 Bi_2O_3-%50 PbO. Tüm parametre sonuçları, 511 keV, 662 keV, 1173 keV, 1274 keV ve 1332 keV enerji aralığında GATE/Geant4 (Geant4 Application for Tomographic Emission) simülasyon kodu kullanılarak elde edilmiştir. Ayrıca XCOM programı kullanılarak 1 keV ile 1 GeV enerji aralığında gama ışını koruma parametreleri hesaplanmıştır. Böylece, simüle edilmiş GATE/Geant4 sonuçlarının doğruluğu XCOM programı kullanılarak test edildi. Diğer yandan ekranlama malzemelerinin tüm parametrelerinin teorik olarak hesaplanan değerleri birbirleri ile karşılaştırılmıştır. Bu sonuçlar, GATE/Geant4 sonuçlarının XCOM sonuçlarıyla iyi bir uyum içinde olduğunu göstermektedir.

Anahtar Kelimeler: XCOM, GATE, Bi_2O_3, PbO, Radyasyon zırhlama

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1. Introduction

The interaction of high-energy photons with matter is significant for use in radiation medicine, agriculture, engineering, nuclear applications and space technology. With the development of suitable protective materials to reduce the increase in radiation dose alongside in developed the technology, it is possible that living beings are affected as little as possible by radiation [1, 2]. The most effective way of protection from radiation is to put a protective material between the radiation source and the living thing. Because the importance of shielding in radiation protection is known, studies where different shielding materials are developed are important studies in the nuclear field. Over the last years, efforts to find new shielding materials to replace Pb’ in terms of cost and easy usability, a heavy metal, have increased. A wide variety of materials designed for use as radiation shields exist in the literature [3-11].

Glasses are one of the appropriate materials that may be used for radiation shielding because of its high transparency to visible light, it has relatively high densities, it can be formed in great volumes and controllable properties with changing compositions [12, 13]. In order to understand the structural, mechanical, optical, physical and chemical properties of glasses, both theoretical and experimental studies are carried out by researchers [14-18].

Bismuth Oxide has applications in the electronics, glass and ceramics industries. In electronics, capacitors, pressure sensitive resistors and solid electrolytes, it is used in the ceramic industry to increase the preferability of ceramic materials, and to increase the refractive index of glass when added to glass [19, 22].

For this reason, in this study, the gamma radiation absorption properties of bismuth oxide (Bi_2O_3), and determine the effect of lead oxide (PbO) additive in the shielding of Bi_2O_3.

2. Material and Method

The GATE simulation is an open access software program that performs Monte Carlo calculations for use in areas such as nuclear physics, radiology, and radiotherapy. The XCOM software, on the other hand, can calculate total attenuation cross section, total mass attenuation coefficient data, and partial cross-sections data for the different elements, compounds and mixtures in the photon energy range of 1keV-100GeV using the web infrastructure [23-25].

2.1. Radiation Absorption Parameters

The attenuation coefficient (μ and μ_m) of any material is defined from the exponential attenuation rule known as Beer-Lambert:

$$I = I_0 e^{-\mu x}$$
$$\mu_m = \mu/\rho$$

where I_0 and I are incident and attenuated photon intensities, μ (cm^{-1}) and μ_m (cm^2/g) are linear and mass attenuation coefficients, x (cm) is sample thickness, and ρ is density (g/cm^3) respectively.

HVL is the used to reduce the radiation intensities by one half and TVL is used to reduce the radiation intensities that one tenth.

$$HVL = (In2/\mu)$$
$$TVL = (In10/\mu)$$

MFP is the average distance between two consecutive interactions.

$$MFP = (1/\mu)$$

3. Results and Discussion

This study, the GATE simulation program and XCOM software were used to contribute to the literature and to investigate additional radiation absorbing materials. The linear attenuation coefficient and the half value layer of the Bi_2O_3, PbO, and 50% Bi_2O_3-50%PbO samples have been calculated. Obtained values are given comparatively (Fig. 1 and Fig. 2).

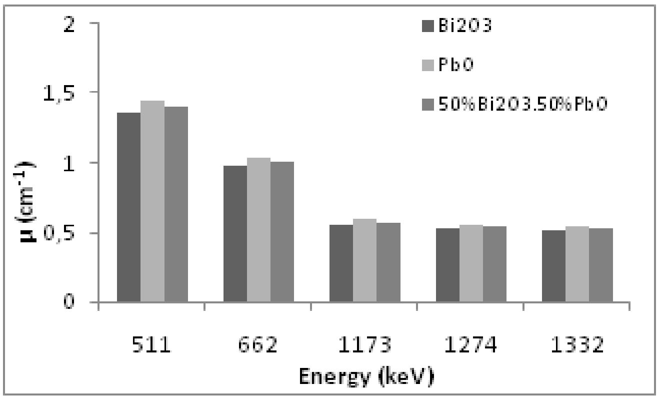

Fig. 1 LAC for samples

Fig 1 has demonstrated that the concentration of PbO added to Bi_2O_3 causes an increase in linear attenuation coefficients of 50% Bi_2O_3-50%PbO. Also, the linear absorption coefficient of uptake appears to diminish as the energy increases.

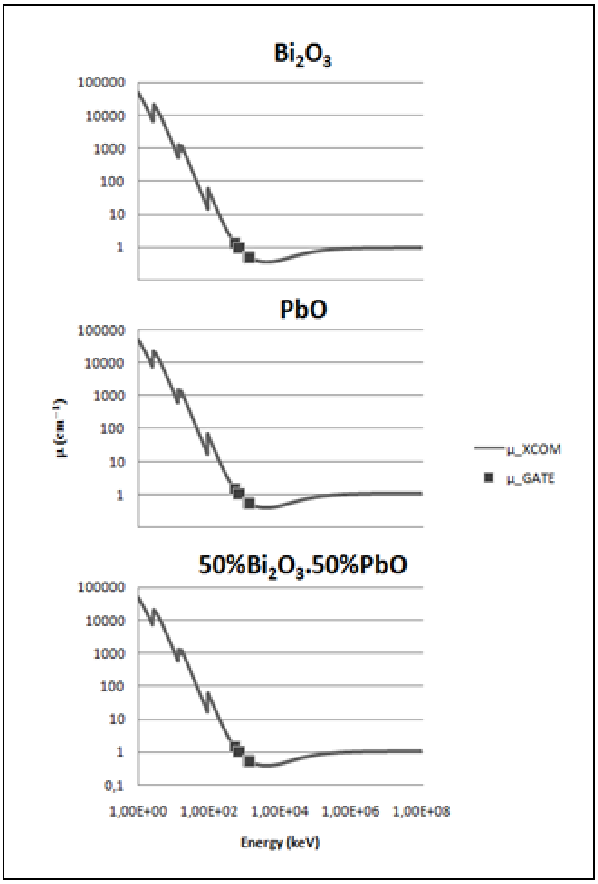

Fig. 2 The GATE values compared with the XCOM values for linear attenuation coefficient

Fig. 2 has demonstrated that the calculated XCOM and GATE values of LAC were compatible with each other.

The calculated HVL values at 0.001 MeV and 10 MeV energy range are shown in Fig. 3.

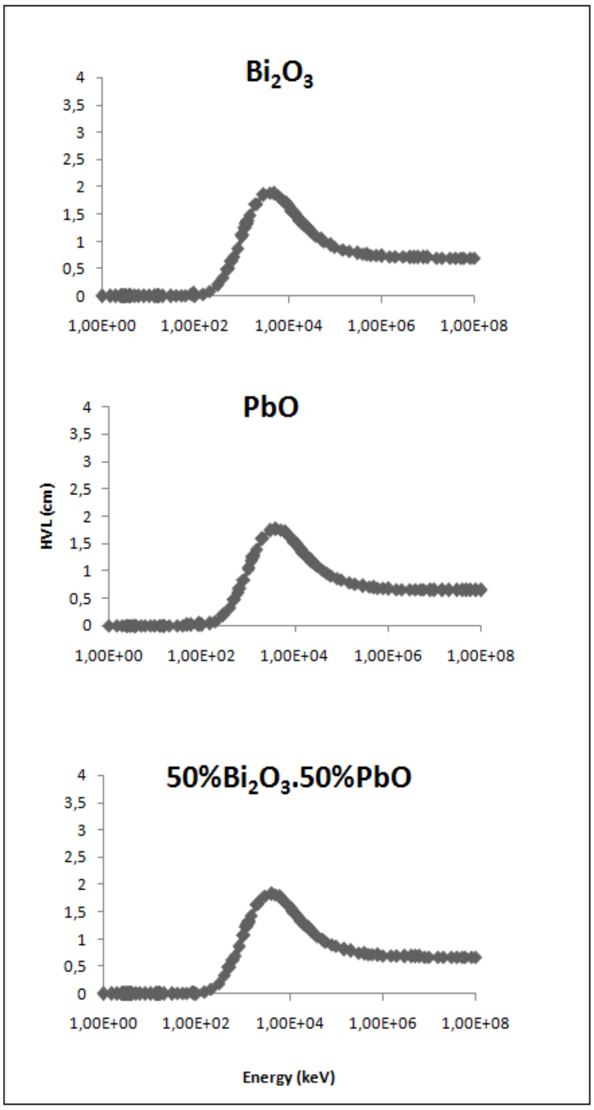

Fig .3 has demonstrated that the concentration of PbO added to Bi_2O_3 causes an decrease in HVL values of 50% Bi_2O_3.50%PbO.

In addition, calculated using the LAC values calculated with the XCOM program HVL, TVL and MFP values are shown in Table 1.

Table 1. HVL, TVL and MFP values

	Bi_2O_3			PbO			%50 Bi_2O_3-%50 PbO		
Energy (keV)	HVL	TVL	MFP	HVL	TVL	MFP	HVL	TVL	MFP
511	0,510	1,6954	0,736	0,481	1,598	0,694	0,496	1,648	0,716
662	0,715	2,3757	1,0318	0,675	2,241	0,973	0,696	2,311	1,04
1173	1,252	4,1588	1,806	1,181	3,926	1,705	1,218	4,045	1,757
1274	1,332	4,4248	1,922	1,258	4,178	1,814	1,296	4,304	1,870
1332	1,374	4,5629	1,982	1,297	4,308	1,871	1,336	4,438	1,928

4. Conclusions and Recommendations

Although there are many studies in the literature comparing the results obtained with the XCOM data, there are limited studies investigating the properties of shielding materials using the Geant4-based GATE simulation.

For this reason, in this study, it was compared with simulated GATE values calculated XCOM values.

5. Acknowledge

In this study, which was conducted to determine the gamma radiation absorption properties of bismuth oxide (Bi_2O_3) and the effect of lead oxide (PbO) additive on the shielding of Bi_2O_3, observed that the GATE simulation program data were compatible with the XCOM data, and Bi_2O_3 absorption values were also determined to increase by the 50% contribution of PbO.

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