International Journal of Computational andExperimental Science and ENgineering (IJCESEN)

Vol. 9-No.4 (2023) pp. 398-401
http://dergipark.org.tr/en/pub/ijcesen

ISSN:2149-9144

Research Article

Theoretical and Experimental Investigation of Gamma Shielding Properties of TiO_2 and PbO Coated Glasses

Arzu COŞKUN[1,2], Betül ÇETİN[3*], İbrahim YİĞİTOĞLU[4], Betül CANIMKURBEY[5]

[1]Vocational School of Health Services, Toros University, 33100, Mersin-Turkey
[2]Amasya University Institue of Science, Amasya University, 05000, Amasya-Turkey
Email:arzu.coskun@toros.edu.tr- **ORCID:** 0000-0003-4771-1558

[3]Amasya University Faculty of Arts and Sciences, Physics Department, Amasya University,05000, Amasya-Turkey
* **Corresponding Author** : **Email:**betulcetin3205@gmail.com- **ORCID:** 0000-0001-9129-2421

[4]Gaziosmanpaşa University Faculty of Arts and Sciences, Physics Department, 60000,Tokat-Turkey
Email:iyigitoglu@yahoo.com - **ORCID:** 0000-0001-9029-0897

[5] Vocational School of Health Services, Amasya University, 05000, Amasya-Turkey
Email:betul.canimkurbey@amasya.edu.tr- **ORCID:** 0000-0003-1900-3722

Article Info:

DOI:10.22399/ijcesen.1367747
Received : 28 September 2023
Accepted : 05 December 2023

Keywords

GATE,
XCOM,
TiO_2,
PbO,
Gamma

Abstract:
This manuscript has investigated the effect of TiO2 and PbO-coated glasses on radiation absorption properties to develop alternative materials for radiation shielding. The shielding properties of glass materials coated with oxides were calculated experimentally with a gamma spectrometer with NaI(Tl) detector and theoretically with the XCOM computer program and GATE simulation program. Within this scope, the shielding properties of TiO_2, Pb0, and Pb0 doped TiO_2 glasses at 511, 662, 1274 keV gamma energies were calculated. The results obtained showed that 50% Pb0 contribution can increase the shielding properties of TiO_2 glasses. Also, it has been observed that the experimental and theoretical results obtained are compatible with each other.

1. Introduction

Developing protective materials that are suitable to reduce the effects of increasing radiation dose is important with the development of technology. Placement of a shielding material between the radiation source and the living being is the best way to protect from radiation. Radiation protection materials are used to protect radiation workers and patients from the harmful effects of exposure to ionizing radiation, such as x-rays, gamma rays, and neutrons, which are used in many fields [1]. Due to the importance of shielding in radiation protection, studies on the development of protective materials in the nuclear field have gained momentum [1]. Radiation absorption properties of various materials have been examined by many scientific studies such as granite [2], concrete [3], historical building [4], polymer [5], steel [6], steel and iron slags [7], glasses [8-11] and marble [12].

The use of TiO_2 as a coating element for thin films is advantageous due to its photocatalytic properties, low toxicity, thermal stability, and dielectric properties [9].
In addition to experimental studies, simulation programs are important in shielding studies.
For this reason, the purpose of the development of alternative materials that can be used in radiation shielding, absorption properties of TiO_2, Pb0, and Pb0 doped TiO_2 glasses at 511, 662, 1274 keV gamma energies investigated experimentally and theoretically.

2. Material and Methods

2.1 Experimental Procedure

PbO and TiO_2 solutions were prepared using the lead (II) oxide (powder, <10 µm, Sigma Aldrich), Titanium dioxide (powder, 5 µm, Sigma Aldrich), poly (methyl methacrylate) (PMMA, ThermoScientific), and Toluene (Merck). 1 mL of toluene was added to 60 mg of PMMA, thoroughly mixed, and kept at 50 °C for 24h to obtain a homogeneous transparent solution. A 0.5 mg sample was weighed and 2 mL of stock PMMA solution was added and mixed at 500 rpm at 50 °C for 2h.

Glass sheets were washed with isopropyl alcohol to remove metals and organic contaminants from the glass surface. Then prepared solutions were coated on a glass sheet by spin coater at 2500 rpm two times.

2.2 Theoretical Procedure

The XCOM and GATE simulations used in the study were made with the same method in the article on the effects of BiO_2 additives on the radiation absorption of PbO [1].

The linear attenuation coefficient is calculated from the Beer-Lambert's Law given by Eq.1:

$$I = I_o e^{-\mu x} \quad [1]$$

where *μ(LAC)* is the linear attenuation coefficient, *x* is the thickness of the glass samples, *I* and I_0 are the net count which are the measured with and without the absorber, respectively.

The mass attenuation coefficient of a material characterizes how easily it can be penetrated by a radiation beam and it is given by Eq. 2:

$$\mu_m = \frac{\mu}{\rho} \ (cm^2/g) \quad [2]$$

where ρ is the density of the material [8].

The material thickness required to halve incident gamma radiation is referred to as the Half Value Layer (HVL) given by Eq.3 [9]:

$$HVL = \frac{ln2}{\mu} \ (cm) \quad [3]$$

Mean Free Path (MFP) is the average distance the gamma-ray moves without interacting with the material, and it is given in Eq. 4 [10]:

$$MFP = \frac{1}{\mu} \ (cm) \quad [4]$$

3. Results and Discussions

In this study, the radiation attenuation properties of glass materials obtained by coating PbO and TiO_2 nanopowders were investigated. First of all, mass absorption values were calculated in the photon energy range of 511, 662, and 1274 keV with GATE and XCOM theoretical programs. The absorption properties of the obtained glass materials were examined in a laboratory environment using a NaI(Tl) detector and point sources. Additionally, using LAC, MFP and HVL values were calculated using the Eq. 1, 3, and 4. Graphs of the theoretical and experimental LAC (μ) values given Fig.1- Fig. 3.

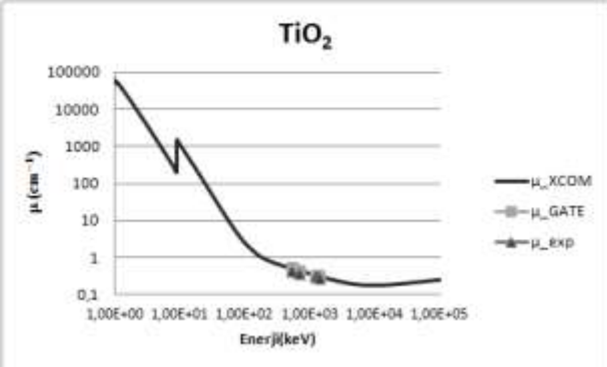

***Figure 1**. LAC values of TiO_2*

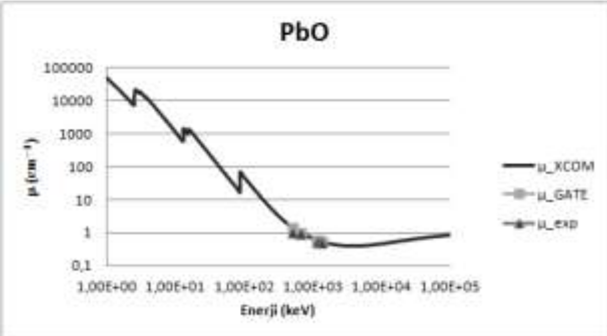

***Figure 2**. LAC values of PbO*

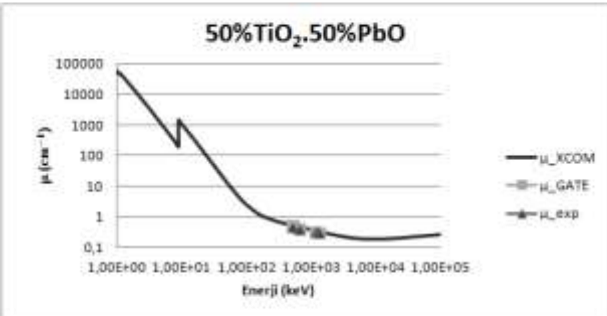

***Figure 3.**LAC values of the mixture*

In the study, it was observed that while the absorption coefficient of PbO at 511 keV energy value was 1.44 cm^{-1}, this value decreased to 0.806 cm^{-1} with the addition of TiO_2. It was observed that as the energy increased, it decreased from 0.55 cm^{-1} to 0.38 cm^{-1}. The decrease in the linear absorption coefficient at 1274 keV can be considered as the emergence of the Compton effect rather than the material contribution. While the photoelectric effect

is dominant at 511 keV, the Compton effect becomes dominant as the energy increases.
The theoretical and experimental HVL and MFP graphs obtained by substituting the LAC value in Eq. 3 are as follows.

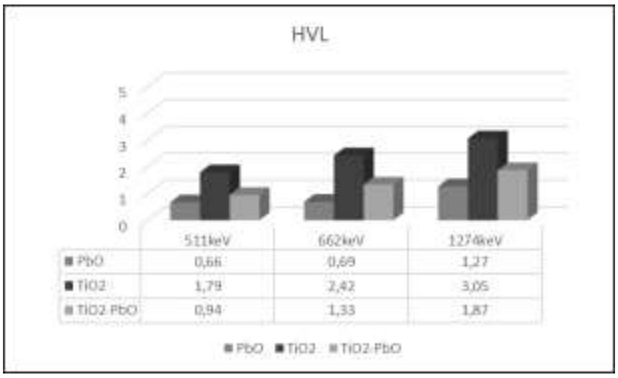

Figure 4. *Experimental HVL values*

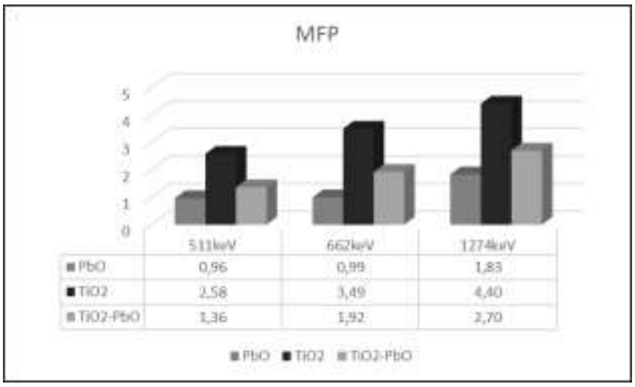

Figure 5*. Experimental MFP values*

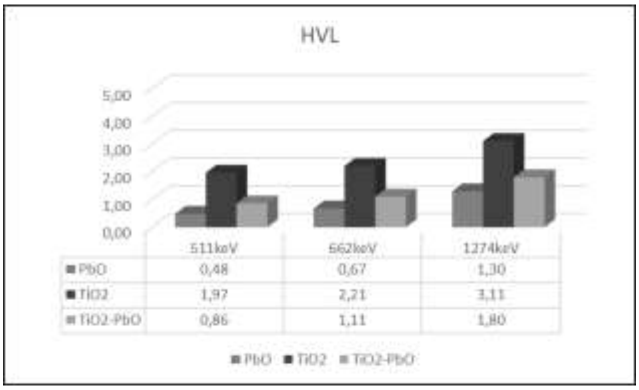

Figure 6.*Theoretical HVL values*

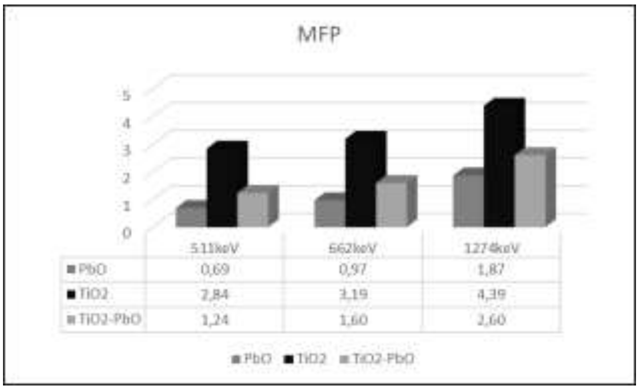

Figure 7. *Theoretical MFP values*

Figure 4 and Figure 5 give experimental HVL and MFP values, and Figure 6 and Figure 7 give theoretical HVL and MFP values. It is seen that the experimental values are compatible with the theoretical values.

4. Conclusions

As a result of the study, experimental and theoretical values were found to be compatible with each other. According to the absorption coefficients obtained, 50% PbO addition to TiO_2 increases the absorption properties of the prepared glass material. At the same time, a decrease in the absorption property was observed as the energy value increased. This situation is compatible with the interaction of gamma radiation with matter.

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
- **Acknowledgement:** This work is supported by Amasya University Scientific Research Projects Department (BAP) under Project No. FMB-BAP-18-0315.
- **Author contributions:** The authors declare that they have equal right on this paper.
- **Funding information:** The authors declare that there is no funding to be acknowledged.
- **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.

References

[1] A. Coşkun, B. Cetin, (2023). The Effect of Lead Oxide on the Change in Gamma Ray Protection Parameters of Bismuth Oxide. ,*European Journal of Science and Technology*, 47, 18-21.
[2] B. Mavi, (2012). Experimental investigation of γ-ray attenuation coefficients for granites, *Annals of Nuclear Energy*, 44, 22–25.
[3] I. Akkurt, H. Akyildirim, B. Mavi, S. Kilincarslan, C. Basyigit, (2010). Gamma-ray shielding properties of concrete including barite at different energies, *Progress in Nuclear Energy*, 52(7), 620–623.

[4] T. Singh, U. Kaur, P.S. Singh, (2010). Photon energy absorption parameters for some polymers, *Ann. Nucl. Energy*, 37(3), 422–427.

[5] O. Agar, (2018). Investigation on Gamma Radiation Shielding Behaviour of CdO–WO3–TeO2 Glasses from 0.015 to 10 MeV, *Cumhuriyet Sci. J*., 39-4, 983-990.

[6] H. Singh, K. Singh, L. Gerward, K. Singh, H.S. Sahota, R. Nathuram, (2003). ZnO–PbO–B2O3 glasses as gamma-ray shielding materials, *Nucl. Instrum*. *Methods,* 207, 257–262.

[7] G. Demircan, E. F. Gurses, B. Aktas, S. Yalcin, A. Acikgoz, G. Ceyhan, M. V. Balak, (2023). Sol–gel synthesis of Si-ZnO, Ti-ZnOand Si-Ti-ZnO thin films: Impact of Si and Ti content on structural and optical properties, *Materials Today Communications*, 34 105234.

[8] K.S. Krane, W.G. Lynch, (1989). Introductory nuclear physics. *Phys. Today*. https://doi.org/ 10.1063/1.2810884.

[9] M.I. Sayyed, (2016). Bismuth modified shielding properties of zincborotellurite glasses*. J. Alloys Compd.* 688, 111–117. https://doi.org/10.1016/ j.jallcom.2016.07.153.

[10] V.P. Singh, N.M. Badiger, J. Kaewkhao, (2014). Radiation shielding competence of silicate and borate heavy metal oxide glasses: comparative study. *J. Non-Cryst. Solids* 404, 167–173. https://doi.org/ 10.1016/ *J.JNONCRYSOL*.2014.08.003.

[11] A. Coşkun, B. Cetin, (2023). The Effect of Lead Oxide on the Change in Gamma Ray Protection Parameters of Bismuth Oxide. *European Journal of Science and Technology Special Issue 47, pp. 18-21*. DOI:10.31590/ejosat. 1234613

[12] Y. Savaş, B. Başaran, B. Cetin, (2023). The Effect of Marble Powder Additive at Different Ratios on the Radiation Absorption Parameters of Barite Based Concretes. *International Journal of Computational and Experimental Science and ENgineering (IJCESEN) 9 (4) 376-38.*DOI:10.22399/ijcesen. 1322248