การสร้างแก้วกำบังรังสีจากแก้วปลอดตะกั่วที่มีค่าดรรชนีหักเหสูงที่เตรียมจากทรายภายในประเทศ

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บทคัดย่อ

เป็นที่รู้กันดีว่าแก้วตะกั่วซึ่งเป็นแก้วที่มีค่าดรรชนีหักเหสูงสามารถกั้นรังสีได้ดี แก้วปลอดตะกั่วได้ถูกพัฒนาขึ้นมา เนื่องจากความเป็นพิษของตะกั่วต่อสุขภาพและสิ่งแวดล้อม ในการศึกษานี้ ส่วนผสมแก้วปลอดตะกั่วถูกเตรียมจากส่วนผสมหลักที่เป็นทรายจากแหล่งชุมพรปริมาณ 40 % (โดยน้ำหนัก) และแบเรียมคาร์บอเนตปริมาณต่างๆระหว่าง 6 ถึง 30 % (โดยน้ำหนัก) พบว่า เนื้อแก้วที่มี $BaCO_3$ ปริมาณ 30 % มีค่าสัมประสิทธิ์การดูดกลืนรังสีแกมมาจาก แบเรียม-133 เป็น 0.233 cm^{-1} สรุปได้ว่า แก้วปลอดตะกั่วที่เตรียมเหล่านี้มีคุณสมบัติในการกั้นรังสีแกมมาได้ดี และเป็นวัสดุที่เป็นมิตรกับสิ่งแวดล้อม

คำสำคัญ: แก้วกำบังรังสี แก้วปลอดตะกั่ว แก้วที่มีค่าดรรชนีหักเหสูง ทรายภายในประเทศ

Fabrication of Radiation Shielding Glasses Based on Lead-free High Refractive Index Glasses Prepared from Local Sand

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Abstract

Lead glasses that show high refractive index are the best know and most popular for radiation shielding. Due to harmful effects of lead and considering the health as well as the environmental issues, lead-free glasses were developed. In this work, content of Chumphon sand was fixed at 40 % (by weight) as a main composition but concentrations of $BaCO_3$ were varied from 6 to 30 % (by weight). It was found that the absorption coefficient of the glass samples containing 30 % $BaCO_3$ was 0.233 cm^{-1} for Ba-133. The density was also measured. It can be concluded that the prepared lead free glasses offered adequate shielding to gamma radiation in comparison with the lead ones. These glasses were one of the environmental friendly materials.

Keywords: radiation shielding glass, lead free glass, high refractive index glass, local sand

Introduction

Among with the many directions in which radiation is being used, such as the use of atomic energy and radioactive isotopes, radiation protection has become a big topic. There are many pieces of apparatus, such as color television sets and medical uses. Since glass is a solid as a transparent material, there is a great effect being put into devising types that protect against small amounts of radiation without loss of transparency. The shielding capacity depends on the kind of radiation. It is determined in principle by the kinds and numbers of elements passing through the substance and by density. The shielding capacity does not depend on the bonding conditions of the glass. The photon attenuation coefficient is an important parameter for characterizing the penetration and diffusion of gamma radiation and X-rays in multi-element materials. It is characteristic of the glass state that the capacity for self-restoration of the defects caused by irradiation is very great, and above all, since it is transparent, its greatest merit is that it can be used as an inspection window. Glasses have been developed which accomplish the double task of allowing visibility absorbing radiation like gamma radiation, thus protecting the observer. A good shielding glass should have high absorption cross-section for radiation and at the same time irradiation effects on its mechanical and optical properties should be small. By comparison between the materials, lead glass is the best known for radiation shielding for gamma radiation because of its high density and atomic number. Most of lead-containing glasses are high refractive index glasses that exhibit the value of refractive index (RI) higher than 1.52.

Due to harmful effects of lead and considering the health as well as environmental issues, commercially manufactured lead-free glass offers adequate shielding to gamma radiation in comparison with lead one. The previous works found that barium compounds seem to satisfy to replace lead in the lead free glass production, and the preparation of lead free glasses using local sands and barium carbonate as the main compositions gave a high potential for high quality fabrication of the high refractive index glasses.

The linear attenuation coefficient (μ) and mass attenuation coefficient (μ_m) of glasses containing oxides of B, Ba, Bi, Cd, and Pb were measured at 356- 1332 keV. It was found that a comparison of shielding properties of these glasses with standard shielding materials like lead, lead glass and concrete have proven that they have a potential application as transparent radiation shielding.

In this study, the gamma radiation attenuation characteristics of the lead-free glasses that prepared from the local sand and barium carbonate as the main compositions have been studied for photon from gamma radiation sources in the energy of 356 keV.

Experimental

The cylindrical colorless lead free glass samples were prepared into eight samples in the laboratory scale. The glass mixtures contained 150 g weight in each sample. The content of Chumphon sand was fixed at 40 % (by weight) as a main composition but concentrations of barium carbonate ($BaCO_3$) were varied from 6 to 30 % (by weight). Well-mixed and dried powders mixtures were put in a ceramic crucible. The crucibles were then melted in an electric furnace, in normal atmosphere at 1250°C with 4 h dwelling time. All samples were prepared in parallel with the lead glass and with the same concentrations. After the complete melting, the molten glasses were removed, poured into a cylindrical steel mould; 3 cm in diameter and 1 cm in thickness, and then cooled down to room temperature. The transparent and bubbles-free cylindrical glass samples were obtained.

Prior to measure the properties, the surface of the glass samples were ground and polished to a mirror finish with a 0.3 μm alumina paste. The refractometer; Reyner Duplex II with a refractometer fluid $n_D \leq 1.79$ was used to determined the values of the refractive index (RI) of the prepared glass samples. It was operated at room temperature and using the sodium light. The density of each sample was measured by the Archimedes principle at 25°C with the analytical balance; Mettler Toledo AG104, using the distilled water as the immersion fluid.

The gamma attenuation characteristics of the prepared lead free glasses have been studied for photon in the energy at 356 keV about 5 μCi Ba-133 from Isotope Products Laboratories; a monoenergetic gamma radiation source that was procured as a sealed source. The gamma radiation transmission measurements were done under a narrow beam counting geometry employing the NaI(Tl) detector; Teledyne Brown Engineering, with the scaler; Ludlum Measurements Inc. Model 2000. The samples having various concentrations of $BaCO_3$ were interposed in the beam. The counts under the full energy absorption peak of the recorded photon spectrum were determined. From the transmitted photon intensity (I) and the incident photon intensity (I_0), for a density ρ and a thickness x of the sample, the linear attenuation coefficient (μ) and the mass attenuation coefficient (μ_m) are given by the following expression:

$$\mu = \ln(I/I_0)/x \quad (1)$$

$$\mu_m = \mu/\rho \quad (2)$$

Results and Discussion

From the experiments, the density of the lead free and lead glass samples were found to be 2.607 to 2.831 and 2.768 to 3.192 gcm^{-3}, respectively, as shown in Table 1. The measured values of RI were 1.480 to 1.605 and 1.510 to 1.635, respectively, as shown in Table 2. The experimental values of μ and μ_m for gamma-ray at 356 keV were found to be between 0.201 to 0.233 cm^{-1} and 0.0771 to 0.0823 cm^2g^{-1}, respectively. While as, those of prepared lead glass samples were 0.220 to 0.273 cm^{-1} and 0.0795 to 0.0855 cm^2g^{-1}, respectively.

Finally, the comparison of the radiation shielding properties between the lead free and the lead glass samples, it was found that the experimental values of μ and μ_m of the lead free glass samples were less than those of the lead ones approximately 11 % and 3%, respectively.

Table 1. The measured values of the density, and the attenuation coefficient of the prepared colorless glass samples.

$BaCO_3$ concentration %(by weight)	Density (gcm^{-3}) (at 25°C)		Attenuation coefficient at 356 keV			
			lead free glass		lead glass	
	Lead free glass	lead glass	μ (cm^{-1})	μ_m (cm^2g^{-1})	μ (cm^{-1})	μ_m (cm^2g^{-1})
6	2.607	2.768	0.201	0.0771	0.220	0.0795
12	2.715	2.844	0.215	0.0792	0.228	0.0802
18	2.740	2.867	0.218	0.0796	0.233	0.0813
20	2.750	2.904	0.220	0.0800	0.237	0.0816
24	2.761	2.985	0.224	0.0811	0.246	0.0824
26	2.794	3.081	0.228	0.0816	0.261	0.0847
28	2.801	3.143	0.230	0.0821	0.268	0.0853
30	2.831	3.192	0.233	0.0823	0.273	0.0855

Table 2. The comparison of the measured values of the refractive index at 589 nm.

$BaCO_3$ concentration % (by weight)	RI	
	Lead free glass	Lead glass
6	1.480	1.510
12	1.505	1.526
18	1.518	1.541
20	1.532	1.558
24	1.543	1.584
26	1.561	1.603
28	1.587	1.621
30	1.605	1.635

The advanced works found that a low density glass samples will give rise less attenuation than a high density ones, and the greater the energy of the gamma-rays the less the attenuation.

Conclusions

In conclusion, the lead free glasses that are one of the environmental friendly materials can be used as the gamma radiation shielding glasses. A variety of the prepared glasses could be produced both in terms of clarity and radiation shielding. It can be concluded that these glasses have shielding properties comparable to those of the lead glasses.

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