X-RAYS AND GAMMA RAYS SHIELDING GLASSES DRIVEN FROM QUARTZ, BISMUTH ORE AND BARIUM OXIDE

ABSTRACT

The development of cost-effective and sustainable radiation-attenuating materials is crucial for enhancing radiation safety in various applications. This study reports the development of novel transparent X and gamma-ray attenuating glass systems using glass sand and bismuth oxide, with an empirical formula of $\{85[25(Quartz) + 35H_3BO_3 + 40Na_2CO_3] + 15BaO\}_{(100-y)}$ + $[Bismuth\ ore]_y$. The glasses were characterized using XRF, EDX, XRD, FTIR, and physical density measurements, revealing improved opto-physical and radiation shielding properties. The Bi ore and quartz contain 60.68 wt.% and 89.97 wt.% of Bi_2O_3 and SiO_2, respectively. The physical densities of the glasses increased from 2.92 g/cm^3 to 3.53 g/cm^3 with increasing Bi_2O_3 content, indicating improved mass attenuation. XRD analysis confirmed the amorphous nature of the glasses, while FTIR spectroscopy revealed BO_3 and SiO_4 groups. Attenuation experiments with Cs-137 (662 keV) showed that the sample Y25 (25 wt.% Bi oxide) has the lowest Tenth Value Layer (TVL) and Mean Free Path (MFP), indicating improved gamma-ray attenuation compared to commercially available Pb/Ba glasses. This study demonstrates the novelty of using locally sourced materials to fabricate radiation-attenuating glasses with potential applications in radiation safety, highlighting its potential for industrial scalability.

BACKGROUND HISTORY OF THE INVENTION

The development of radiation-attenuating glasses has increasingly focused on replacing toxic lead (Pb) oxide with heavy metal oxides like bismuth oxide (Bi_2O_3) and barium oxide (BaO) to achieve enhanced gamma-ray and neutron shielding. Prior studies have demonstrated that Bi_2O_3-doped glasses, such as $LiBi_5OBEu_2$ [1] and TBBE systems [2], outperform Pb-based glasses in attenuation efficiency, while Bi_2O_3/epoxy composites and BaO-doped borate glasses improve shielding, optical properties, and mechanical stability [3]. Silica-based glasses combined with Bi_2O_3 and B_2O_3 provide structural stability, thermal robustness, and superior radiation attenuation, making them viable for radiological applications. Sodium carbonate (Na_2CO_3) and boric acid (H_3BO_3) further enhance glass formation by reducing melting temperatures and improving network stability. Despite these advances, an invention gap exists in utilizing locally sourced bismuth ore and glass sand with BaO to create cost-effective, sustainable, and transparent radiation-shielding glasses. The present invention addresses this gap by developing novel glass compositions using quartz, bismuth ore, and BaO, optimized for optical transparency, structural integrity, and superior radiation attenuation, offering a scalable and environmentally friendly alternative for medical, nuclear, and industrial applications.

DETAILED DESCRIPTION OF THE INVENTION

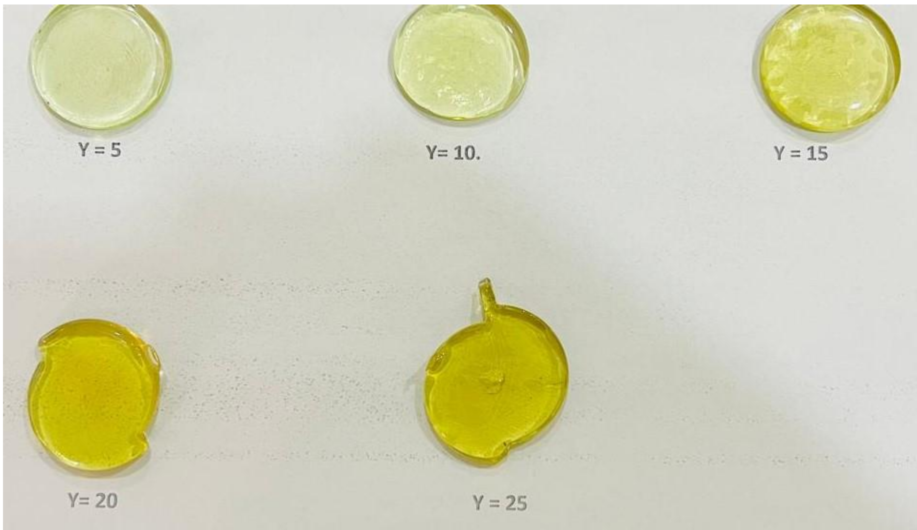
Quartz was sourced and pulverized by grinding and sieving for Energy Dispersive X-ray Fluorescence (EDXRF) analysis. Bismuth ore was retrieved from artisenal mines and processed for characterization. Sources of mineral ores and the process of ore processing has been provided in ref. [4]

The quartz composition, analyzed via EDXRF (Thermo Scientific XRF Analyzer, Serial No: 9952120), revealed 89.74 wt.% SiO_2 with trace metallic oxides. Bismuth ore was examined using Variable Pressure Scanning Electron Microscopy (VPSEM, JEOL JSM IT-300 LV) and Energy Dispersive X-ray (EDX) mapping, confirming 60.68 wt.% Bi with elements like C, O, Cu, Al, and Si. SEM revealed amorphous morphology with uniform particle distribution.

Glasses with the formula $\{85[25(Quartz) + 35H_3BO_3 + 40Na_2CO_3] + 15BaO\}(100 - y) + [Bismuth\ ore]y\ (y = 5 - 25\ wt.\%)$ were fabricated via melt-quenching as shown in Figure 1. Powdered quartz, H_3BO_3, Na_2CO_3, BaO, and bismuth ore were mixed, preheated at 400°C for 1 hour, melted at 930°C for 2 hours, cast into preheated molds, and annealed at 450°C for 1 hour. Polished glasses were transparent, bubble-free, and exhibited yellow hues with increasing Bi content.

Glass Characterization Techniques

i. Mass Density: Measured using an MH-300A densitometer, density increased from 2.92 g/cm³ to 3.53 g/cm³ with higher Bismuth ore content, enhancing radiation attenuation.
ii. Optical Properties: UV-visible spectroscopy (Jenway 741501) showed indirect band gap energies (1.54–2.24 eV) and refractive indices increasing with Bi_2O_3, except for for glass with 10 wt.% of bismuth ore, due to ore-related defects. The range of the refractive index is 2.24-2.49 depending on bismuth ore content.
iii. XRD Analysis: Conducted using a Thermo Scientific ARL'XTRA diffractometer, confirming amorphous structure with broad humps at 20°–35°.



iv. FTIR Spectroscopy: Recorded via Agilent Cary 630 FTIR, revealing Bi-O, B-O, and Si-O bonds, indicating structural integrity.

Figure 1: Enginered Glass Samples for characterization with Y = wt.% bismuth ore in the glass samples

Figure 2: Radiation Shielding Glass. Customizable dimensions, up to 10 cm thick, designed for optimal protection in nuclear power plants, atomic energy, nuclear medicine, and more.

CLAIMS

Radiation Attenuation: X-ray shielding (Siemens Polymobil 2, 40–80 keV) and gamma-ray attenuation (Cs-137, 662 keV) experiments showed the glass with 25 wt.% of bismuth ore has the lowest Tenth Value Layer (TVL) and Mean Free Path (MFP), outperforming commercial Pb/Ba glasses. Linear and mass attenuation coefficients decreased with increasing photon energy, with glasses containing 20 and 25 wt.% exhibiting superior X-ray shielding due to higher bismuth ore content.

Results

The glasses demonstrated enhanced density, optical transparency, and radiation shielding, with Y=25 wt.% of bismuth ore showing optimal gamma-ray attenuation. The use of locally sourced bismuth ore and quartz ensures cost-effectiveness and sustainability, making these glasses suitable for medical, nuclear, and industrial radiation shielding applications.

CONCLUSION

This invention introduces a novel, sustainable approach to fabricating transparent radiation-attenuating glasses using locally sourced bismuth ore and quartz, with the composition $\{85[25(Quartz) + 35H_3BO_3 + 40Na_2CO_3] + 15BaO\}(100-y) + [Bismuth\ ore]y$. The glasses, particularly the composition with 25 wt.% of bismuth ore, exhibit superior X-ray and gamma-ray shielding, high density (up to 3.53 g/cm^3), and optical transparency, outperforming conventional Pb/Ba glasses. Humanity stands to gain safer, cost-effective, and environmentally friendly radiation shielding solutions for medical, nuclear, and industrial applications, reducing reliance on toxic lead-based materials and promoting sustainable use of natural resources.

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