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SAFE AND RADIATION-PROOF OBSERVATION GLASS FROM MULTI-COMPONENT BOROTELLURITE GLASS

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ABSTRACT

In this work, $15B_2O_3$-$60TeO_2$-$11Bi_2O_3$-$10Li_2O$-$1Ho_2O_3$-$3Yb_2O_3$ glass sample was synthesized by using the melt-quenching technique. The density test applies the Archimedes' principle and obtained 5297.5 kg/m^3 which may be attributed by the presence of heavy elements in the glass sample. The radiation shielding properties such as mean free path (MFP) and half-value layer (HVL) were investigated by using the Phy/X-PSD software. The values obtained were relatively better than typical radiation-shielding glasses. The improvement that occurred in the radiation shielding parameters may be contributed to the high-density value of the glass sample and therefore, potentially be the alternative to a transparent observation glass for radiation shielding purposes.

Keyword: *Borotellurite glass, radiation shielding, Phy-X/PSD*

1. INTRODUCTION

Globally, radiation can come from many sources such as nuclear reactors, medical instrument, and even outer space. Prolonged human exposure to hazardous radiation can lead to many problems such as cancer, infertility, and many more (Sayyed et al., 2021). Therefore, a proper and good radiation shielding material is needed to encounter this issue. Radiation shielding works by absorbing or attenuating the incoming radiation energy. Thick concrete walls were famous for being efficient radiation shielding material. However, they have many shortcomings such as being prone to crack, opaque, non-portable, and heavy (Kaur et al., 2019). Meanwhile, lead-based glasses were used in many fields such as clinical and experimental laboratories due to their high density. Unfortunately, lead is toxic, and has low melting point and low transparency (Kaur et al., 2019).

On the other hand, the alternative borotellurite glass has the advantages of high transparency, high thermal stability, high chemical durability, high refractive index, and many other benefits (Hisam & Yahya, 2019). Inclusion of bismuth oxide has turned the overall effective atomic number (Z_{eff}) to be higher that helps in attenuating the incoming radiation as well as increasing the overall density (Sayyed, 2016). Lithium oxide is known as good neutron shielding. Hence, this research was attempted to explore the potential of $15B_2O_3$-$60TeO_2$-$11Bi_2O_3$-$10Li_2O$-$1Ho_2O_3$-$3Yb_2O_3$ glass sample as the rigid, transparent yet safe and radiation-proof glass.

2. METHODOLOGY

$15B_2O_3$-$60TeO_2$-$11Bi_2O_3$-$10Li_2O$-$1Ho_2O_3$-$3Yb_2O_3$ glass sample was prepared by using the conventional melt-quenching technique. The high purity (>99.99%) chemical powders of boron oxide (B_2O_3), tellurium oxide (TeO_2), lithium carbonate (Li_2O), bismuth oxide (Bi_2O_3), holmium oxide (Ho_2O_3) and ytterbium oxide (Yb_2O_3) were weighed and mixed. The mixture was grinded for an approximately an hour to achieve homogenous. The mixture was transferred into alumina crucible and melted at 1100°C for 90 minutes. The molten mixture was then quenched into stainless steel mould and annealed at 350°C for 6 hours to reduce internal stress. Eventually, the sample was cooled to room temperature.

The density was determined by using the Archimedes' principle with toluene as the immersion liquid. The calculation of the density is by using this relation;

$$\rho\left(\frac{kg}{m^3}\right) = \frac{w}{w - w'} \times \rho' \quad (1)$$

where w is the weight of the glass in air, w' is the weight of the glass sample in toluene and ρ' is the toluene's density (867 kg/m^3). The radiation shielding parameter was investigated and simulated by using the Phy-X/PSD software in the energy range of 15 keV to 15 MeV.

3. FINDINGS

The density of $15B_2O_3$-$60TeO_2$-$11Bi_2O_3$-$10Li_2O$-$1Ho_2O_3$-$3Yb_2O_3$ is 5297.5 kg/m^3. The high density obtained might be contributed by the heavy elements of tellurite (159.6 g/mol) and bismuth oxide (465.96 g/mol) as well as the rare earth elements of holmium oxide (377.86 g/mol) and ytterbium oxide (394.08 g/mol).

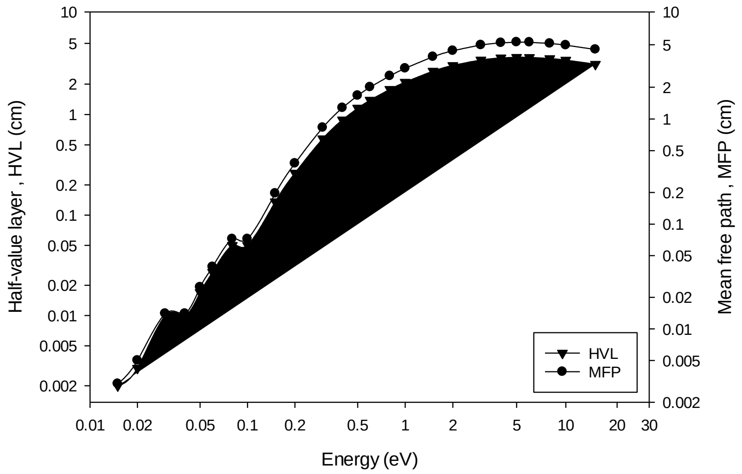

Figure 1 Plot of Half-Value Layer (HVL) and Mean Free Path (MFP) Against Energy of $15B_2O_3$-$60TeO_2$-$11Bi_2O_3$-$10Li_2O$-$1Ho_2O_3$-$3Yb_2O_3$ Glass Sample

MFP and HVL were among crucial parameters used to check the suitability of the material for radiation shielding. Mean free path (MFP) explains the estimated successive distance travel between photon interactions. A lower MFP is desirable in a material, suggesting that more interactions between photon and material within a shorter distance to occur. Meanwhile, the half-value layer (HVL) can be described as the minimum thickness required by a material to reduce the incoming radiation intensity to half of its original value. Therefore, a lower HVL value indicates less thickness is needed to cut down the intensity; hence, reducing production cost and also enhancing portability.

The radiation shielding parameters were determined and plotted as shown in Figure 1. The increasing trend of both parameters infers that for a higher incoming radiation energy, a thicker glass is needed to attenuate the photons (HVL), and a farther distance is travelled by the photons (MFP). In comparison, Table 1 shows that the MFP and HVL of the glass sample were relatively better as compared with other few radiations shielding glass material at around 0.6 MeV.

Glass Composition	HVL (cm)	MFP (cm)
$15B_2O_3$-$60TeO_2$-$11Bi_2O_3$-$10Li_2O$-$1Ho_2O_3$-$3Yb_2O_3$	1.4846	2.1428
30BiBTe (Halimah, Azuraida, Ishak, & Hasnimulyati, 2019)	2.0281	2.9265
$25PbO$-$40B_2O_3$-$25Na_2O$-$5Li_2O$-$5SiO_2$ (Salama, Maher, & Youssef, 2019)	2.218	3.201
$20Na_2CO_3$-$20Si_2O$-$55H_3BO_3$-$5WO_3$ (Esawii, Salama, El-ahll, Moustafa, & Saleh, 2022)	2.1522	3.1056

Table 1 HVL and MFP Values of Certain Glasses.

4. CONCLUSION

$15B_2O_3$-$60TeO_2$-$11Bi_2O_3$-$10Li_2O$-$1Ho_2O_3$-$3Yb_2O_3$ glass sample was successfully synthesized. The density and radiation shielding properties were investigated. The high-density value of the glass sample has enhanced the radiation shielding parameter of the glass sample such as HVL and MFP. Therefore, the borotellurite glass sample can be suggested to be the alternative for a safe and radiation-proof observation glass.

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