UNIVERSITI TEKNOLOGI MARA

STRUCTURAL, ELASTIC, OPTICAL AND RADIATION SHIELDING PROPERTIES OF (79-x)B_2O_3-$x$$TeO_2-20Li_2O-0.5Ho_2O_3-0.5Yb_2O_3$ GLASSES

MAZLINI BINTI MAZLAN

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ABSTRACT

A mixed glass former (MGF) system refers to a glass network consists of two or more different glass-forming oxides, commonly including B_2O_3 (borate), TeO_2 (tellurite), P_2O_5 (phosphate), or SiO_2 (silicate). These glasses exhibit nonlinear and non-additive variations in their properties when the ratio of different glass formers is adjusted while maintaining a constant modifier composition, a phenomenon known as the mixed glass former effect (MGFE). A recent trend in MGF research is the use of MGFE to enhance optical, mechanical, elastic, thermal, structural, and shielding properties for advanced applications. In this study, a series of mixed glass formers (MGF) with compositions $(79\text{-}x)B_2O_3\text{-}xTeO_2\text{-}20Li_2O\text{-}0.5Ho_2O_3\text{-}0.5Yb_2O_3$ ($x = 0$ - 50 mol%) were synthesized via melt-quenching. XRD confirmed their amorphous nature and structural analysis revealed interaction between TeO_2 and B_2O_3, with bridging oxygen (BO) in BO_4 units decreasing at $x \geq 40$ mol%, leading to more non-bridging oxygen (NBO) in BO_3 units. Raman spectroscopy showed increasing TeO_2 content caused depolymerization, reducing TeO_4 units. DC conductivity exhibited a non-linear trend, peaking at $x = 30$ mol% and slightly declining at $x = 40$ mol%, due to the mixed glass former effect (MGFE). Elastic moduli (C_L, K_e and Y) followed a similar pattern, with the lowest values at $x = 40$ mol%, aligning with peak conductivity due to the increase in NBO resulting from the formation of TeO_3 and BO_3 units, which weakens the glass network rigidity, as evidenced by the FTIR results. The presence of all elements in the glass system was confirmed by EDS analysis. Ultrasonic analysis using bulk compression and ring deformation models showed maximum K_{bc}/K_e at $x = 40$ mol%, indicating reduced ring deformation. Meanwhile, UV-Vis spectroscopy showed a general decrease in Direct (E_{opt}) and Indirect ($E_{opt'}$) optical band gap, and an increase in refractive index (n), except at $x = 40$ mol%, due to the alternating dominance of BO and NBO in the MGFE region. Absorption spectra revealed nine peaks from the $^5I_8$ ground state to excited Ho^{3+} states and one peak for Yb^{3+}, $^2F_{7/2}$ to excited states. A negative bonding parameter indicated mainly ionic interactions for Ho^{3+}, while an increase in Ω_2 suggested greater covalency and ligand polarizability, except at $x = 40$ mol% due to TeO_2-B_2O_3 interaction. Reduced in Ω_4 and Ω_6 values indicated weakened glass rigidity from higher NBO content. Luminescence spectra showed green (526 nm) and red (642 nm) emissions from Ho^{3+} ($^5F_4 \rightarrow {}^5I_8$ and $^5F_5 \rightarrow {}^5I_8$), along with a novel peak at 738 nm ($^5F_4 \rightarrow {}^5I_7$), linked to Yb^{3+}-Ho^{3+} energy transfer. The green and red stimulated emission cross-sections were $(0.324–0.347)\times10^{-20}$ cm^2 and $(0.387–0.423)\times10^{-20}$ cm^2, highlighting applications in lasers, green displays, and photonics. Radiation shielding properties were analysed for 15 keV–15 MeV photons using Phy-X/PSD. Higher Te content improved atomic number-dependent parameters (MAC, Z_{eff}) and density-related parameters (LAC, MFP, HVL, TVL), enhancing shielding performance due to increased glass density. The results obtained highlight the potential of borotellurite glasses for diverse applications, including nonlinear optical devices, electronics, and optoelectronics, as well as advanced laser, green display, and photonic technologies.

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Oxide glasses have attracted wide attention due to their important scientific and technological applications. Numerous oxide glass systems, including phosphate, borate, tellurite, silicate, borosilicate, borophosphate, have been studied and synthesized to explore their potential applications [1-3]. High-density, high-atomic number oxide glasses are being considered as replacements for current materials due to several advantages such as transparency, stress-relief properties, high ionic conductivity, and cost-effectiveness. Achieving the optimal combination of glass components is critical to maximizing its potential and efficiency while minimizing drawbacks [3]. Tellurite glass possesses a high refractive index, excellent mechanical and chemical resistance, great thermal stability, and broad transmission range extending to 6 μm [3-6]. Basic tellurite glass composed of a TeO_3-trigonal pyramid with a lone pair of electrons at the equatorial position and a TeO_4-trigonal bipyramid [6]. The inclusion of alkaline modifiers like Na, K, Li, and others caused the formation of non-bridging oxygen (NBO) by converting the Te atom from TeO_4 through TeO_{3+1} to TeO_3 [7-9].

On the other hand, boron oxide (B_2O_3) stands out as an exceptional oxide glass former recognized for its transparency, low refractive index, low melting point [8], high thermal stability [9], high toughness and good chemical durability [4]. B_2O_3 also has other important properties such as excellent solubility of rare earth ions and ease to prepare, which make it more suitable for this study [10, 11]. B_2O_3 boroxol rings composed of 3-coordinated, B_3 and 4-coordinated, B_4 boron units are typically observed. Doped B_2O_3 often features superstructural units like diborate, triborate, pentaborate, tetraborate, pyroborate, and orthoborate [10]. The transformation of three coordinated triangular boron units [BO_3] into four coordinated boron tetrahedral units [BO_4] occurred upon the addition of a modifier such as Na_2O into the glass network, resulting in increasing the dimensions and interconnection within the glass network [11]. Hence, borate glasses hold promise for diverse applications in areas including nonlinear optical devices, electronics, and optoelectronic [12].