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Ag Effect On Lithium Magnesium Borate Thermoluminescence And Structure

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Abstract: Thermoluminescence (TL) refers to the light emission from materials that were previously exposed to ionizing radiation and subsequently heated, and is of great importance for radiation dosimetry applications. TL can be enhanced through the incorporation of dopants, and Ag has been shown to increase TL in a variety of borate host materials. Here, the incorporation of Ag into Li2MgB4O7, which has yet to be studied for TL and other luminescence phenomena, was investigated. Li2MgB4O7 and the Ag-doped equivalent were synthesized via conventional high-temperature solid-state methods, and the role of Ag as a TL dopant was explored via X-ray diffraction (XRD), The results indicate that Ag incorporation induces significant structural modifications that directly influence the material thermal, and luminescent properties, which could have potential applications in radiation dosimetry, phosphor lighting, and optical sensing.

Keywords: Thermoluminescence, Borate glass, Phosphor doped, sliver co-doped.

1. INTRODUCTION: The incorporation of silver ions into a lithium magnesium borate host lattice serves as a case study for the influence of dopants on thermoluminescence and structure. The crystallographic framework of the material remains intact upon doping, but the observed transformations have potential implications in material science and enable additional studies on luminescence and energy transfer. Borate materials with silver doping are considered interesting candidates for luminescence studies due to the strong UV excitation. Such

luminescence properties lend themselves to applications in optical devices, sensing, and matched materials for optical pumping [1].

Silver has been investigated as a luminescent dopant in different host matrices. Data on the structural and thermoluminescence characteristics of silver-co-doped lithium magnesium borates are important due to the increasing demand for commercially useful phosphors. As the supply of rare-earth-based materials becomes limited, a search is on for materials based on naturally abundant elements. Scintillators based on alkaline earths and borates have been prepared using readily available starting materials and are used by several labs. The understanding of the impact of luminescent dopants in borate matrices is still limited [2]

The purpose of this research is to investigate various TL characteristics and kinetic parameters of lithium- and strontium-modified borate glass doped with dysprosium and phosphor oxides. Among these characteristics are the following: kinetic parameters, effective atomic number, sensitivity, linearity, repeatability, and glow curve.

2. METHODS

2.1 Samples Preparation

Series of Li4P(BO3)3 glasses of chemical compositions (85-x) H3BO3 + 15% Li2CO+ 2% Mg + x Ag (x = 0. 3 and 0.6 mol%)

Co-doping lithium magnesium borate (LMB) with silver ions modifies the thermoluminescent properties and crystalline structure of the host matrix. Silver-co-doped LMB is prepared by melt-quenching technique Li2B4O7, MgO and AgNO3, the thermoluminescence pulse height after β-irradiation increases with Ag concentration, indicating the introduction of additional trap sites. Widely used for thermoluminescence and photoluminescence applications, silver ions can replace lithium or magnesium, providing various coordination states.

Weighing and mixing the compounds well was done with a milling machine. The mixture was melted in an alumina crucible for one hr using an electric furnace a NabGmbH at a temperature of 1300 oC. Syarikat Pustaka Elit of Johor Bahru, Malaysia, supplied the Li2CO3 (purity 99 + %), H3BO3 (purity 99.98%), Mg (purity 99.9%), and Ag (purity 98%). Pouring and quenching the liquid glass over a well-polished, pre-heated steel plate was the next step after melting. To remove the mechanical stress, the samples were subsequently annealed at 400 °C for three hours. Tables provide the nominal sample compositions. given in Tables 1

Table 1: Compositions and coded of co-doped glass samples.

Samples code	Concentration (mol %)			
	Li_2CO_3	Mg	H_3BO_3	Ag
B1	15	2	82.995	0.3
B2	15	2	82.99	0.6

2.2 Samples Characterizations

Through the use of X-ray diffraction (XRD) measurement and diffraction software analysis, the amorphous nature of all samples is confirmed. It functions at 40 kV and 30 mA, and it employs Cu Kα radiation (λ = 1.54 A). At a scanning rate of 0.05 degrees per second, the XRD profiles of powdered samples are acquired within the 2θ = 5–90-degree range. Field emission scanning electron microscopy (FESEM) is used to examine the phase homogeneity, cleanliness, and particle morphology of these glasses.

Pellets with a diameter of 10.0 mm and a thickness of about 2.0 mm are produced by pressing the mixture at 120 MPa. then samples read with TL reader 4500 model Harshaw 4500.

3. RESULTS AND DISCUSSION

3.1 X-ray diffraction pattern (XRD)

X-ray diffraction patterns confirm that low concentrations of Ag do not modify the orthorhombic structure of LMB; structure refinement indicates that Ag occupies both substitutional and interstitial sites, altering the coordination of nearby ions the precursor affects crystallinity and may facilitate the formation of a silver-rich phase. In addition, the LiBO3 and MgBO3 crystal structures are responsible for the two peaks that occur at 20-30o and 40-50o, respectively [3].

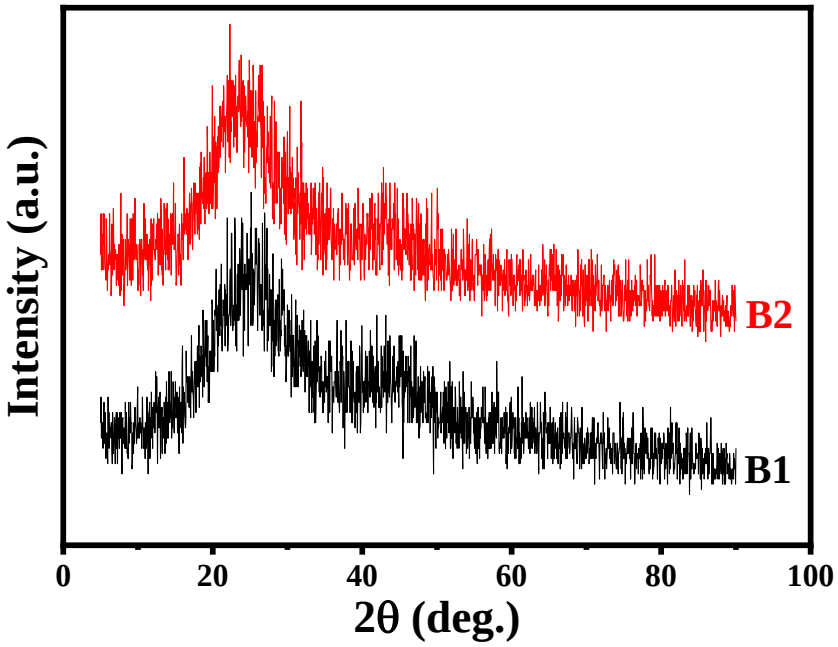

Figure1: XRD patterns of doped and Co-doped glass samples.

3.2 Field emission scan electron microscope (FESEM)

Figures 2: illustrate the FESEM pictures of samples that have not been doped and those that have been doped. A clear, homogenous morphology is seen, with no grains. The FESEM picture correctly identified the constituents present in this morphology[4].

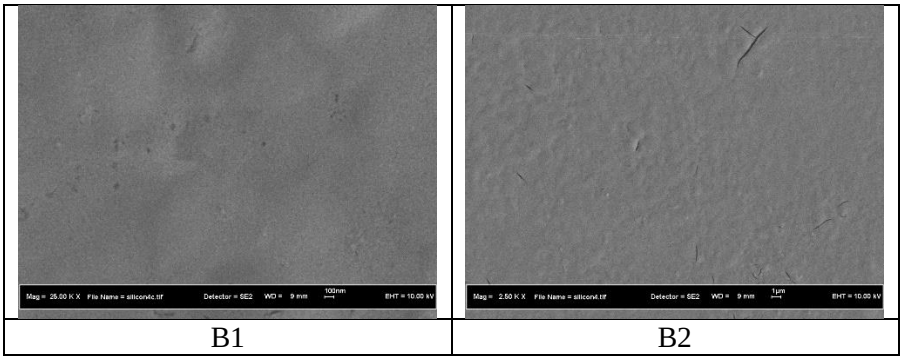

Figure2: FE-SEM images of Co-doped glass samples

3.3 Annealing procedure

Annealing is a technique that gets rid of any leftover TL signals, brings back the TL sensitivity, and gets rid of the unstable low-temperature glow peaks [5]. various TL materials need various annealing schedules. To find the best combination of time and temperature for the pre-irradiation annealing, four samples of Co-doped were heated at different temperatures between 100 and 300 °C for 15 to 60 minutes, and 50 Gy doses were utilized. Figure 3 shows that the glass samples had the lowest standard deviation of their dent after being heated to 100 oC. As part of a typical pre-irradiation annealing technique, all the samples were heated at this temperature for 60 minutes. Figure 4 demonstrates that LBMg had the best repeatability when it was heated to 100 oC for 60 minutes:Ag (0.6% Ag mol %)

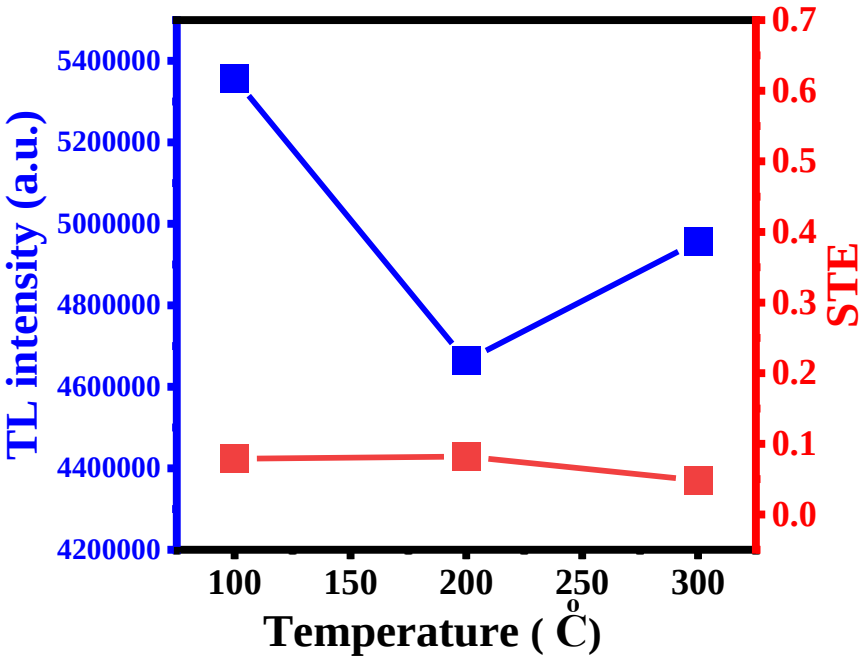

Figure 3: The temperature utilized for pre-irradiation annealing the LMB:Ag (0.6%Ag mol %) affects both the TL response and its standard deviation.

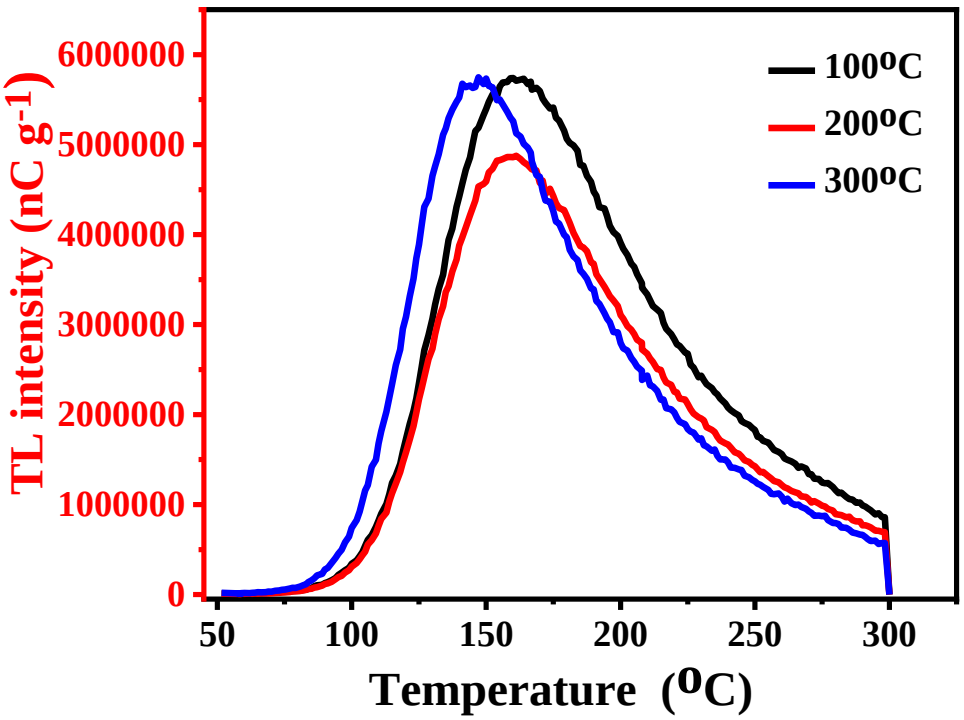

Figure 4: TL glow curves of B2 specimen.

3.4 The TL reaction as a function of heating rate

The heating rate utilized in the TL measurements determines the intensity of the thermoluminescence [6]. The glow curve and peck intensity for glass samples irradiated to 50Gy for Co-doped glasses are shown in Figure (5,6), which also illustrates the influence of heating rate. As the heating rate changes, so does the brightness and where the glow peak appears.The intensity increases as the heating rate increases from 1 to 5 oC s-1, but it drops as the rate increases to 3 oC, most likely because of the thermal quenching effect.

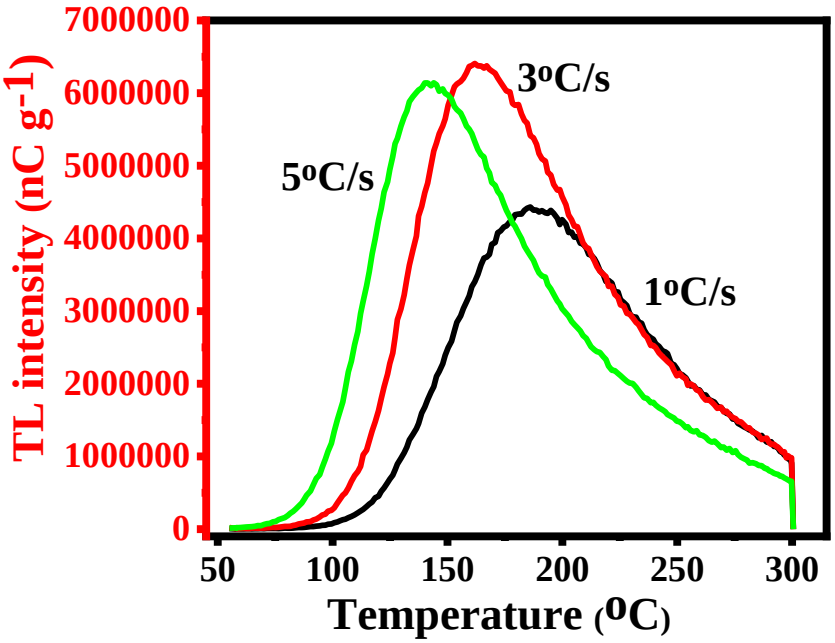

Figure 5: The impact of the heating rate on the location and intensity of the glow peak of the lithium magnisum borate co-doped sliver (0.6Ag mol%)

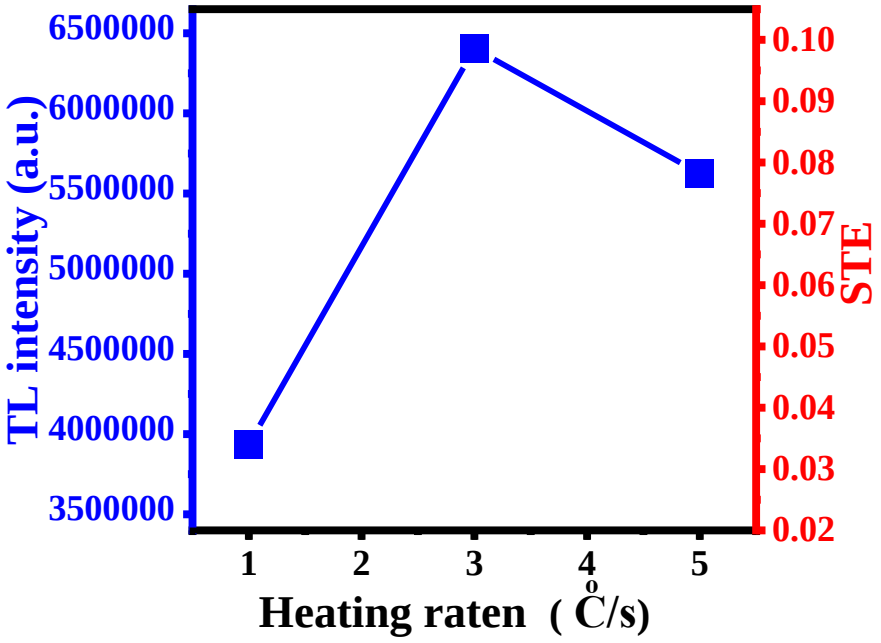

Figure 6: The effect of the heating rate on the peak intensity's position and strength of the lithium magnisum borate co-doped sliver (0.6Ag mol%)

3.4 Glow curve

The mechanistic interpretation of silver-enhanced luminescence involves understanding how Ag influences luminescent processes at the electronic and atomic levels. Silver ions can act as activators or sensitizers, creating electron traps that enhance luminescence efficiency. The incorporation of Ag modifies trap distributions and electron transfer pathways, leading to increased emission intensity as shown in Figure 7. Silver-enhanced luminescence often results from the formation of Ag-related electron traps and their interaction with existing luminescent centers, facilitating energy transfer processes that boost emission [7].

The addition of Ag on LMB (0.6Ag mol%) raises the level of intensity by 1.2 times compared to LMB (0.3Ag mol%). The peak intensity of this improvement occurred at 0.6% Ag and occurred in time with the transition of Tm to a high temperature (160 °C). The concentration quenching theory is mostly responsible for the decrease in the TL light curve intensity above 0.6 mol%[8].

Spectral characterization confirms that these structural modifications are coupled with and may promote the Ag-enhanced luminescence observed. Furthermore, the spectroscopic data suggest wires in either the silver

coordination or the defect center distribution within the borate host lattice that govern the overall tuning of the thermoluminescent behavior [9]. Ultimately, a mechanistic correlation emerges between structural change and luminescence enhancement within the lithia–magnesia borate glass system.

Ag ions were incorporated into the MgB4O7 (mgb) matrix as isovalent cations to study its effect on thermoluminescence (TL) properties. Time-resolved TL analysis shows Ag doping modifies the afterglow profile significantly and introduces a new trap in the 25°–180 °C range. The incorporation of Ag affects the Mg/Ag occupancy of sites a and the presence of significant lattice distortion [10], and Verlet analysis indicates higher Ag concentrations favour a rich mixture of interstitial, substitutional, and nonbonded Ag distributions, creating an inhomogeneous matrix. The changes in the lattice symmetry, dopant distribution, and Mg/B connectivity resulting from Ag incorporation govern the energy transfer channels and defect–energy relay involved in the magic TL glow [11].

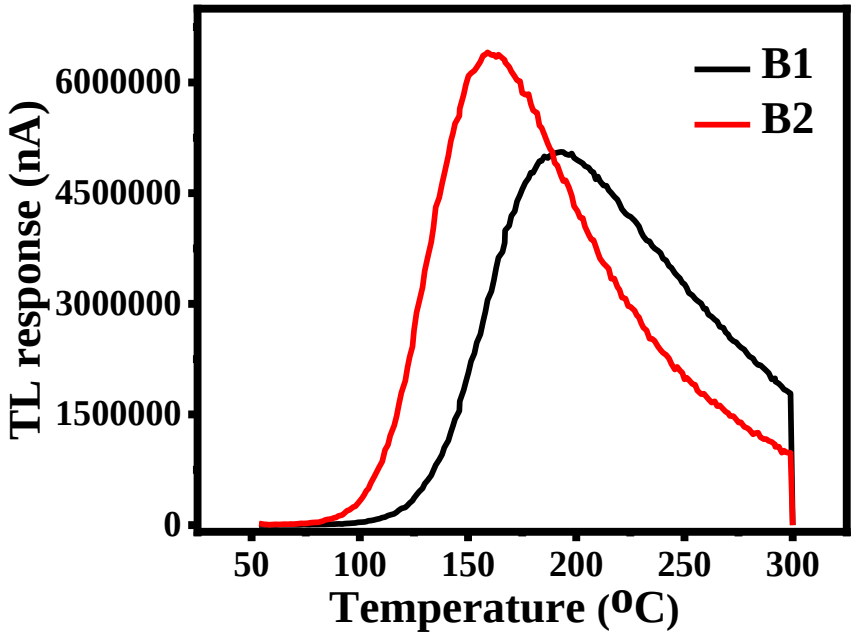

Figure 7: The glow curve of pure LMB with varying amounts of Ag

in which (D_0)is the minimum dose at which the dose response is linear, and TL(D) is the dose response at a dose (D)[12]. Current dosimeters' linearity index is displayed in Figure 8. With f(D)= 1 throughout a large dose range, the perfect TLD material is excellent. The linear behavior is confirmed by our data.

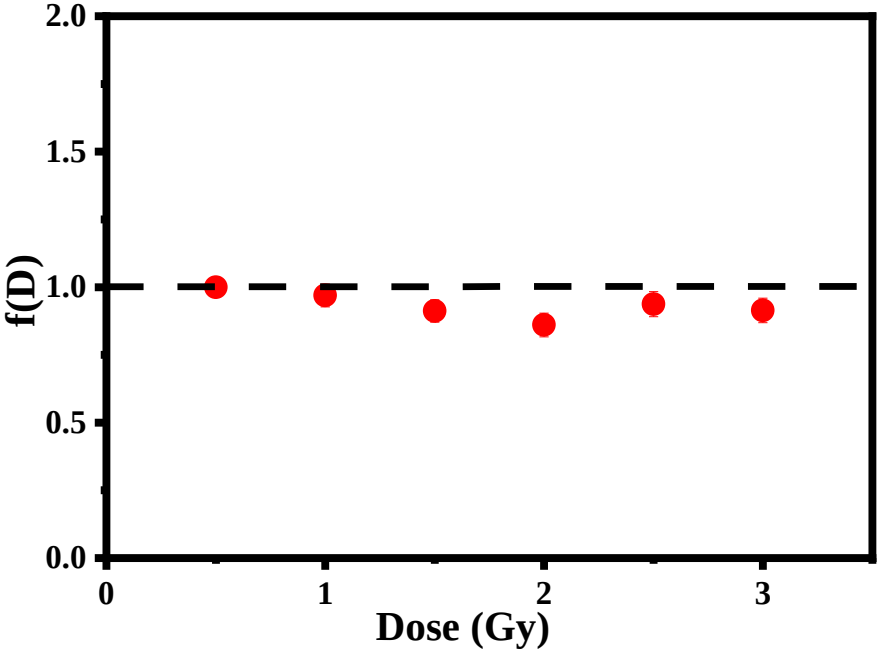

Figure 8: Dose versus the linearity index f(D) for LMB0.6Ag

3.6 Thermal Fading

Many of the suggested samples were annealed and subjected to a 50 Gy gamma treatment to ascertain the thermal fading characteristics of LBMg0.6Ag. To minimize the impact of ambient light, the samples that were suggested were kept in a dark place at room temperature [13]. After exposure began 24 hours and lasted for up to 35 days, the readouts were initiated. The same conditions were used for all measurements. The findings verified a tiny decrease in the TL response across the period considered. Figure 9, shows the glass feeding. The thermal faded for co-doped glass (LBMg0.6Ag), at the rate of about 6.24 per week, and 23.13 per month. The proposed dosimeter's fading was better than another prior research, as shown in Table 2.

Table 2: The outcomes of fading from prior research

Materials	Fading	Reference
LMB0.6Ag	23.13 after 30 days	This study
Saidu et al., 2014	17% after 15 days	[16]

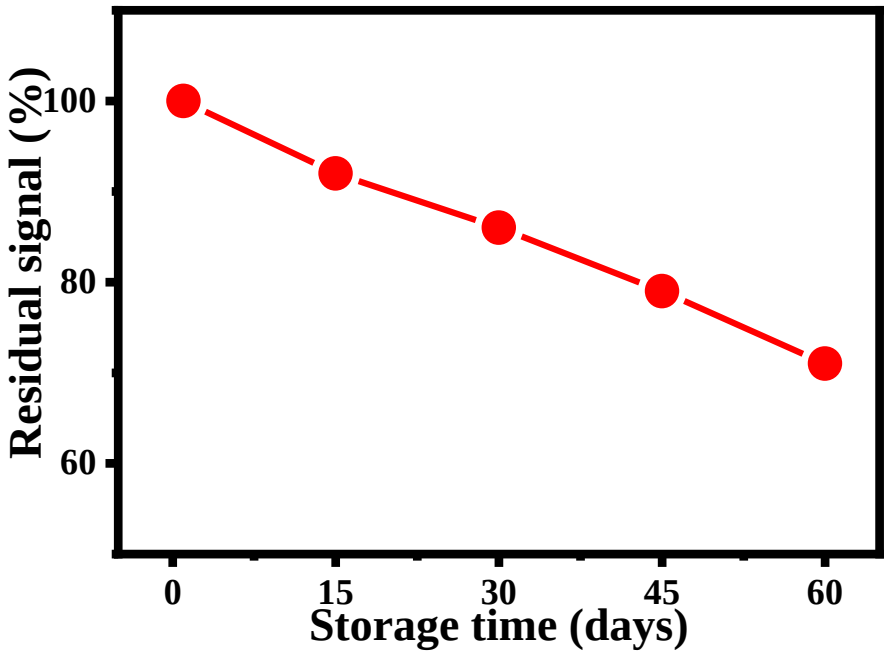

Figure 9: Thermal response fading of lithium magnesium borate co-doped silver. Dose 50 Gy.

3.7 Reproducibility

The material's signals were measured after each irradiation, and ten samples were repeatedly exposed to 50Gy radiation with the appropriate preliminary annealing. Figure 10 shows the results of co-doped glasses. The average sensitivity of the samples decreased slowly at approximately 1.7% per cycle (the relative standard deviations of dosimeters that were replicated produced signals that were lower than 2%. That is what this finding suggests LBMg:0.6Ag is a reusable dosimetric material.

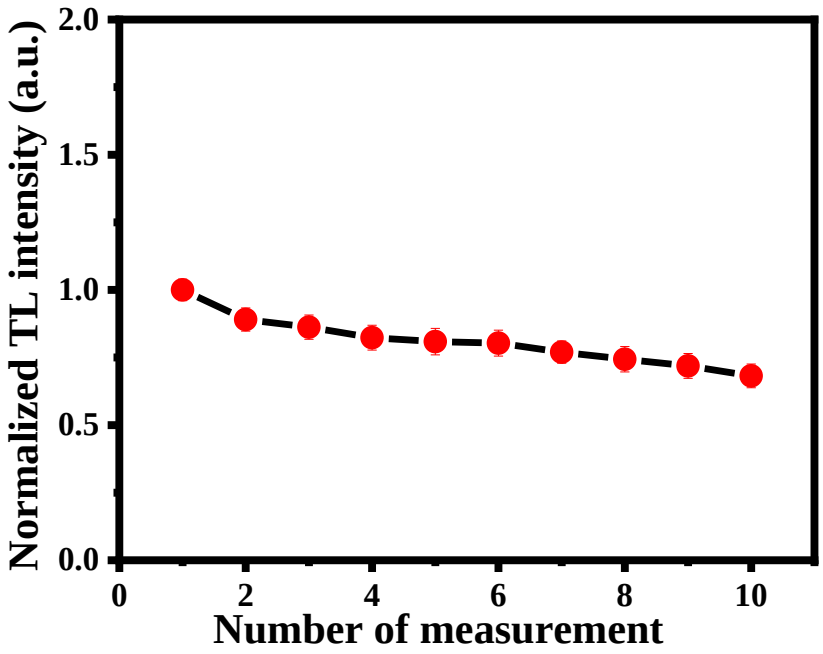

Figure 10: Reproducibility test after 10 times of repeated cycles for LMB0.6Ag exposed to 50 Gy

4. CONCLUSION

The incorporation of silver into the lithium magnesium borate composition [(15%Li2%Mg85-x%B3O5)85−x(Ag2O)x] for Ag concentrations in the range of 0.3 ≤ x ≤ 0.6 mol% leads to significant modifications of both the structural and thermoluminescence properties, enhancing suitability for radiation detection applications. Although preliminary assessment focusing on a comparatively low doping level indicates a still superjacent glassy state and disorder within the framework, thermoluminescence investigations reveal pronounced variations in trap depth distribution, trap density, and kinetic mechanism alongside concomitant enhancement of emission intensity and alteration of the color coordinates. Thermoluminescence remains a partial-to-complete crystalline activator-dominated system at x = 0.3–0.6, whereas the additional presence of both co-dopants renders the system Ag-only luminescent. The thermoluminescence mechanism is further elucidated via comprehensive emission, excitation, XPS spectroscopies complemented by kinetic analyses to develop a coherent model connecting solubility-determined Ag distribution patterns and dopant-induced defect formation to excitation–deactivation pathways

XRD studies indicate the retention of phase and partial amorphous in Ag-doped samples alongside structural modifications dependent on Ag content and host lattice conditions, while FESEM measurements suggest concurrent development of a secondary defect-related network. Further detailed structural inspection via complementary methods contributes to drawing a direct mechanistic link between silver incorporation within the framework and phosphorescence-enhanced thermoluminescence associated with Mg vacancies. Additionally, a high level of linearity in the dose response and reproducibility of the signals are offered. Because of these properties, Ag co-doped lithium magnesium borate is an excellent candidate for use in ionizing radiation dosimetry.

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