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SILVER INFLUENCE OF PHYSICAL AND THERMOLUMINESCENCE PROPERTIES ON LITHIUM-STRONTIUM-BORATE LSBO: AG EXPOSED TO COBALT-60 GAMMA RAY

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ABSTRACT

This work investigates the properties of glow curve of lithium Strontium borate doped sliver glass (LSBO: Ag), subjected to Co-60 gamma irradiation. The glass samples were prepared in different compositions based on 15%Li_2CO_3+2%$SrCO_3$ (83-x) H_3BO_3 +x$AgNO_3$, where x = 0.001, 0.003, 0.005, 0.007, 0.009 and 0.01 mol% by traditional melting quenching method at temperature 1300 ^oC for 1 hour. The structural pattern of glass samples has been identified by X-ray diffraction. The XRD pattern shows that the samples are glasses since there is broader peak appearing in the spectral pattern. FESEM images verify the homogeneous and transmitting surface morphology of all samples. Stable glasses with Hurby parameter ~ 0.5 are achieved. EDX spectra determine the accurate elemental compositions in the samples. Physical properties are determined in terms of glass density, molar volume, polaron radius, inter-nuclear distance, and ion concentration. Glass density is found to increase from 2.45 to 2.46 g cm^{-1} after addition of $AgNO_3$ concentration. The TL intensity at different compositions of lithium borate doped sliver glass after exposed to 50 Gy Co-60 gamma-rays is presented. The results clearly show that the highest TL intensity is found in glass composition of 0.09 mol% of $AgNO_3$.

Keywords: LSBO:Ag, structural-thermale-physics properties, thermoluminescence.

INTRODUCTION

Silver being a multivalent interacts with oxygen and materializes into different phases such as Ag_2O,AgO, Ag_3O_4, Ag_4O_3, and Ag_2O_3 (Bielmann *et al.,* 2002). The different crystalline structures of these oxides exhibit many physiochemical, electrochemical, electronic, and optical properties. Ag_2O and AgO are the most stable and abundant phases (Garner and Reeves, 1954). Ag_2O is under extensive investigation because of its many interesting applications. The silver oxide recently got intention due its potential use in optical memories.

Silver oxide has been studied extensively for the applications in electrical, optical and magneto-optical data storage industries. During the past years, the silver oxide electrode applied as a battery material has been developed to achieve better performance in voltage regulation with longer storage life (Passaniti *et al.,* 1995),(Smith *et al.*, 1997).Owing to its larger optical band gap (2.5–3.1 eV), silver oxide is transparent in the infrared and visible regions to realize a transparent electrode and anti-reflective coating for applications in the opt-electrical field. Furthermore, the silver oxide can be applied in optical and magneto optical data storage. The reflectivity of the silver oxide is higher than 70% over a very wide wavelength range. This has the advantage for the material to be applied in the short-wavelength optical data storage to replace the commonly used organic storage material.

There are several natural and synthetic borates that are used in many industry applications, due to their high impurity in processing plants and are further treated with more qualified finishing products such as boric acid, anhydrous boric, anhydrous borax, borax pentahydrate, borax decorate, borax decahydrate, and sodium perborate) in recrystallizer units. However, the variability of borate crystal chemistry (Yu *et al.,* 2002), which allows the researchers to synthesize different types of the borate to use in high technological areas. One of the most important type of borate is the lithium borate that has been synthesized in a powder form, which resulted from the homogenizing a mixture of the stoichiometric quantities of reactants ($Li_2CO_3$and H_3BO_3) at 750 ^oC for 14 hrs. Lithium borate namely lithium tretraborate and lithium triborate produced by different methods to use for TL dosimetry. Initially lithium borate is a white powder that has an indistinctive order, and it has a melting point of 917 ^oC and solubility is in a moderate range of (1-10%) along with a density of 2.4 g/cm3. Lithium borate possesses numerous technological piezoelectricity (Gorelik *et al.,* 2003). Borate glasses are very interesting amorphous materials considering their specific structure and physical properties, lithium borate is rather new in TL dosimetry compared to lithium tetraborate. Thermoluminescent (TL) dosimetry is an important technology utilized to measure the radiation exposure of this synthetic borate. The technological properties of lithium borate are peculiar to crystallization system. In the recent years, thermoluminescent properties of lithium borate LiB_3O_5 have also attracted many attentions from the scientists and researchers for the medical applications, due to their effective atomic number, which is very close to the biological tissue.

The present study is focused on identifying the physical properties of lithium borate glass that is prepared with different concentrations, followed by an. irradiation process to come out with analysis the glow curve lithium borate.

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EXPERIMENTAL PROCEDURE

Sample preparation

The $Li_4Sr(BO_3)_3$ glasses of compositions (85-x) H_3BO_3 + 15% Li_2CO+ 2% SrO_2 + x $AgNO_3$ (x = 0.001, 0.003, 0.005, 0.007, 0.009 and 0.01 mol%) were synthesized using melt-quenching technique at different concentrations of strontium ions. The powder of the compounds was weighted and well-mixed using 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. The Li_2CO_3 (purity 99.+%), H_3BO_3 (purity 99.98%) and $SrCO_3$ (purity 99.9%), $AgNO_3$ (purity 99%), were supplied by 'Syarikat Pustaka Elit, Johor Bahru, Malaysia'. After completion of melting, the liquid glass was poured and quenched on well-polished pre-heated steel plate. The samples were annealed at 400 ^oC for three hr to eliminate the mechanical stress. Six samples (A1, A2, A3, A4, A5, and A6) with their compositions are summarized in Table-1.

Table-1. Compositions and coded of prepared glass samples.

Samples	Concentration (mol %)			
	Li2CO3	SrCO3	H3BO3	AgNO2
1	15	2	82.995	0.001
2	15	2	82.99	0.003
3	15	2	82.97	0.005
4	15	2	82.95	0.007
5	15	2	82.93	0.009
6	15	2	82.91	0.01

Samples characterizations

The amorphous nature of all samples (at room temperature) was verified using X-ray diffraction (XRD) analysis (Siemens Diffractometer D5000), equipped with diffraction software analysis. It used

Cu Kα radiation (λ = 1.54 A) operating at 40 kV and 30 mA. The XRD profiles on powdered samples were collected in the range of 2θ = 5-90° at a scanning rate of 0.05^o/sec. The particle morphology, purity and the phase homogeneity of these glasses were analyzed via field emission scanning electron microscopy (FESEM). The information about the chemical purity and elemental traces were detected using EDX measurements.

The irradiation was performed using gamma cell, Gamma Ray GC 220 EX machine. The facility is available at the School of Applied Physics, Faculty of Science and Technology, Universiti Kebangsaan Malaysia. The source of gamma ray irradiation used for the gamma cell was Cobalt-60, which was purchased in 2002 with the original dose rate of 9.234 kGy hr-1. However, the current dose rate is 2.263 kGy hr-1. For gamma ray irradiation, both the doped and un-doped samples were placed inside the perspex. The samples were put into the irradiating chamber of the Gamma Cell. Before the samples were exposed, the dose and time of irradiation were calculated first

RESULTS AND DISCUSSIONS

XRD pattern

Figure-1 displays the XRD patterns of undoped LSBO and doped LSBO: Ag glass samples. The patterns and absence of any sharp peaks verify the amorphous structure (Alajerami *et al.*, 2012; Saidu *et al.*, 2014).

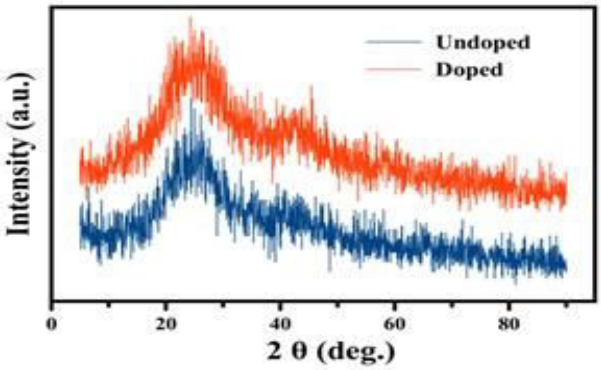

Figure-1. SRD Paterns of undoped LSBO and doped LSBO: Ag glass samples.

FESEM spectra

The FESEM images as illustrated in Figure-2 (2-a) undoped LSBO and, (2-b) doped LSBO: Ag glass samples clearly display the devoid of any grains with homogeneous morphology (Rajesh *et al.*, 2012).

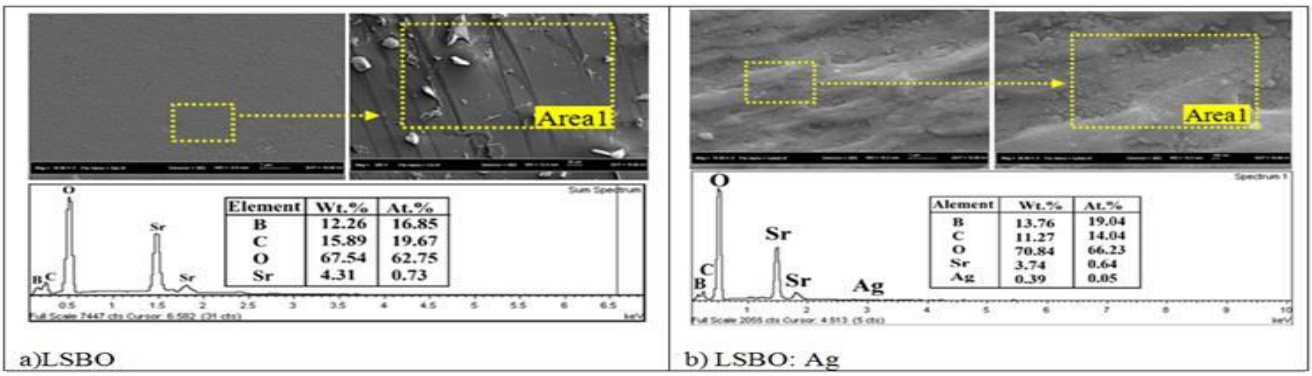

Figure-2. FE-SEM images of (a) $LSBO_2$ Sr mol% and, (b) LSBO: Ag 0.009Ag mol% for glass samples.

Physics parameters

Concentration-dependent physical properties of undoped LSBO (2Sr mol %) and doped LSBO: Ag (0.009Ag mol %) glass samples are enlisted in Table 2.

Glass density (ρ) is determined using Archimedes' principle with toluene as immersion liquid (99.99% purity) from the expression,

$$\rho = \frac{W_a}{W_a - W_i} \times 0.896\ g\ cm^{-1} \quad (1)$$

where Wa and Wi are the weight of glass in the air and liquid respectively. The density of toluene is found to be 0.8696 g cm^{-3} at room temperature (27 ºC). The density is found to increase from 2.45 to 2.46 g cm^{-1} after addition of AgO_2 concentration. This increase is attributed to the following: (i) conversion of $[BO_3]$ triangles into $[BO_4]$ tetrahedral, (ii) enhancement of molecular mass of the glass due to insertion of higher atomic weight of silver, and (iii) increase of the oxygen–boron ratio because of the increase in $AgNO_3$ concentration.

Molar volume of glasses is calculated from,

$$V_m = \frac{M}{\rho} \quad cm^3\ mole^{-1} \quad (2)$$

where Vm is the molar volume in $cm^3\ mole^{-1}$ and M is the molecular weight. Another indication of the glass structure compactness is the increase in density and simultaneous decrease in molar volume (32.6078-31.83cm^3/mol). This decrease is ascribed to the increase in inter-atomic spacing. This decrease is ascribed to the increase in inter-atomic spacing. This results is in accordance to the previous one (Dimitrov and Komatsu, 2010; Tauc, 1974).

Inter-nuclear distance is given by,

$$r_i(\mathring{A}) = \left(\frac{1}{N}\right)^{\frac{1}{3}} \quad (3)$$

The ion concentration is calculated using,

$$N = \frac{mol\% \times \rho \times NA}{Mi}\left(\frac{Ions}{cm^3}\right) \quad (4)$$

where mol% is the mole percent of $SrCO_3$ and $AgNO_3$, ρ is the glass density, NA is Avogadro number and Mi is the average molecular weight of the prepared glass (Ahmed *et al.*, 1984).

According to Shelby (Shelby and Ruller, 1987), three other related physical properties can be calculated after the determination of ion concentration as shown below.The polaron radius (AnChiu *et al.*; Shelby and Ruller, 1987),

$$r_p(\mathring{A}) = \frac{1}{2}\left(\frac{\pi}{6N}\right)^{\frac{1}{3}} \quad (5)$$

Table-2. The physical parameters of glass samples.

physical parameters	Glasses samples	
	Undoped LSBO (2Sr mol %)	Doped LSBO: Ag (0.009Ag mol %)
ρ	2.45	2.46
V_m	31.93	31.83
N	3.77x1022	1.70x1020
r_i (o A)	2.57 x10-12	3.82x10-11
r_p (o A)	1.86x10-12	2.76x10-11

TL intensity

The glow curves are particularly important since they are the main indicators of whether a material can be used for the TL dosimetry purpose. It is desired that the glow curve gives a simple, if possible single peak at around 200 °C. The peak observed at low temperature in the proximity of 100 °C fades away quickly and does not yield any information about the radiation content. This maximum is not symmetric, and the half-width of this peak is wide, these properties of shoulder peak imply that it has a complicated nature. Such maximum is claimed to root from the superposition of a number of local trapping at a certain level (Pekpak *et al.*, 2010). In a similar way peaks observed around 300 °C are not assigned to good TL properties. Another custom to be followed is performing the readings after 24 hours from the irradiation process (Pekpak, *et al.*, 2010). Figure-3 shows a significant property considering the radiation dosimetry potential that LSBO: Ag has the highest thermoluminescence peak of 94.10 nC g^{-1}. Based on these results. the best compositions for these glasses LSBO:Ag are those with [15%Li_2CO_3 + 82.991% H_3BO_3 +2% SrO_2 + 0.009%$AgNO_3$. The optimization of heating rate was recorded with different heating rate. Figure-4 shows the highest TL intensity at heating rate 3 with lower stander diversion.

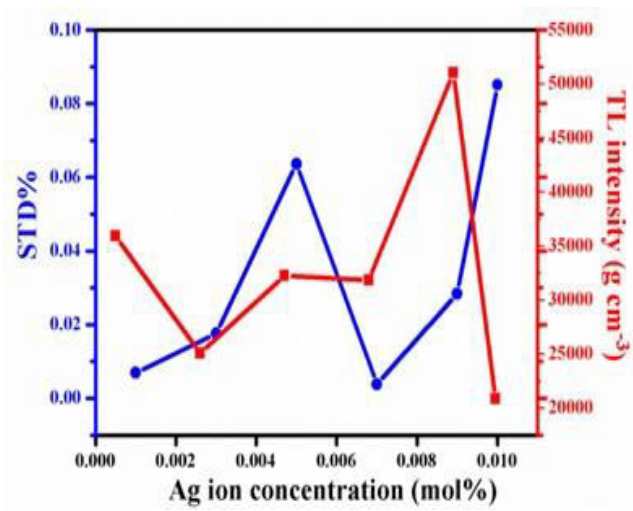

Figure-3. TLD responses of LSBO: Ag with versus concentration of $AgNO_3$.

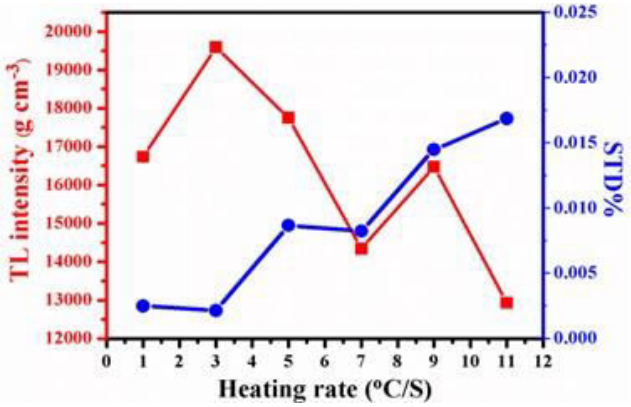

Figure-4. Optimization heating rate of LSBO: Ag glass samples.

CONCULSIONS

Silver ions concentration dependent structural and thermal properties of LSBO: Ag glasses are successfully demonstrated. The highist TL responce was found at concentration of (0.009 mol% Ag). Thermally stable and synthesized LSBO: Ag glasses are reported via conventional melt quenching method. Structures are determined via XRD and FESEM measurements. Elemental compositions are detected via EDX Physical, structural are strongly influenced by the incorporation of Silver ions in the glass network. The values for density, molar volume, ion concentration, inter nuclear distance, polaron radius and thermal parameters of these glasses are also compared. The thermal stability is found to decrease with addition of Ag. The admirable features of the results suggest that the present glass composition has potential for the fabrication of solid state lasers, photonic devices, and optical fibers

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