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Thermoluminescence characteristics of Cu_2O doped Calcium Lithium borate glass irradiated with the cobalt-60 gamma rays

Ismail Rammadhan [a,b,*], Saddon Taha [b], H. Wagiran [a]

[a] Department of Physics, Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia
[b] Department of Physics, Faculty of Sciences and Health, Koya University, Danielle Mitterrand Boulevard, Koya 45, Kurdistan Region, Iraq

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ABSTRACT

The aim of this study is to prepare and investigate the thermoluminescence characteristics for the un-doped and Cu_2O doped calcium lithium borate glass upon adding various Cu_2O concentrations of 0.005% to 0.1 mol%. The glasses were prepared by melt quenching method and irradiated with ^{60}CO gamma-ray having different doses in the range of (0.5–4) Gy, (5–10) Gy, and (20–100) Gy. The amorphous phases were identified for optimization glass samples, effect of heating rate, glowing curves, linearity, sensitivity, fading, reproducibility of response and minimum detectable dose are also studied. The TL sample with 0.02 mol% Cu_2O concentration has higher response compared to the other samples concentration for a delivered dose of 50 Gy, The recorded glow curves consist a dominant peak at 187 °C for a heating rate of 5 °C s^{-1}. However, the value of effective atomic number Z_{eff} is 8.84 for 0.02Cu_2O doped which are near to the atomic number of soft tissue.

1. Introduction

Thermoluminescence Dosimetry (TLD) has been widely applied in the areas of clinical, personal and environmental monitoring of ionizing radiation. It is an important science, in which normally very low radiation doses need to be measured and to be in a fast, simple and easy way. Several research works have been conducted to find a better dosimeter material. Borates are chosen because of its near tissue equivalent absorption coefficient (Z_{eff}=7.42), easy preparation, low cost and high sensitivity compared to other TL materials [6,7]. This enables the measurement of the absorbed dose in the tissue exposed to ionizing radiation. Usually the doped thermoluminescence material gives good thermoluminescence signal compared to the un-doped thermoluminescence material. The doping introduces the defects in the matrix that help to enhance the thermoluminescence signal. The objective of this study is to investigate new material based on borate glasses combined with calcium, lithium and doped with copper which can be used for thermoluminescence dosimeter. In this work, glass has been chosen as the structure of phosphor as it has been revealed to be used as a thermoluminescence dosimeter.

2. Material and methods

Calcium lithium borate (CLB) glasses in the system (90-x) H_3BO_3–10Li_2CO_3–x$CaCO_3$ with x=5, 10, 15, 20, 25, 30 and 35 mol% were prepared using melt- quenching method. The glasses were doped with different concentrations of Cu_2O with compositions (80-y) H_3BO_3–10Li_2CO_3–10Ca CO_3–y Cu_2O and y=0.005, 0.01, 0.02, 0.04, 0.06, 0.08 and 0.1 mol%.The materials were obtained in powdered form from Sigma - Aldrich Company, Germany, with purities of 99%. The precursors were weighed using high sensitive electronic balance (Precisa XT 220A), and they were mixed by utilizing milling machine for 30 min in an alumina crucible. The samples were melted in electric furnace for 60 min at 1300 °C. As the required viscosity was achieved, the melt was quenched on stainless steel plates followed by annealing at 400 °C for 3 h in another furnace. Later on, the samples were cooled down to room temperature. This was done to reduce the thermal stress. The electric furnaces used were available at the Nuclear Laboratory, Department of Physics- University Technology Malaysia. The compositions of the prepared samples are illustrated in Tables 1 and 2.

In order to check the amorphous state of the samples, X-ray diffraction (XRD) analysis was carried out. Energy dispersive X-ray (EDX) analysis was performed to measure the composition of elements present in Cu_2O doped (CLB) glasses that consequently lead to the determination of effective atomic number (Z_{eff}) of these samples. The samples were irradiated at room temperature using ^{60}Co gamma - rays source, the source is a gamma cell 220 Excel

* Corresponding author at: Department of Physics, Faculty of Sciences and Health, Koya University, Danielle Mitterrand Boulevard, Koya 45, Kurdistan Region, Iraq.
E-mail address: ismail.rammadhan@koyauniversity.org (I. Rammadhan).

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Table 1
Nominal compositions of the un-doped H_3BO_3-Li_2CO_3-$CaCO_3$ glass samples.

Sample No	*Composition (mole %)*			Melting temperature (°C)
	H_3BO_3	Li_2CO_3	$CaCO_3$	
CLB1	85	10	5	1300
CLB 2	80	10	10	1300
CLB 3	75	10	15	1300
CLB 4	70	10	20	1300
CLB 5	65	10	25	1300

Table 2
Nominal compositions of the Cu_2O- doped $80H_3BO_3-10Li_2CO_3-10CaCO_3$ glass sample.

Sample No	*Composition (mole %)*				Melting temperature (°C)
	H_3BO_3	Li_2CO_3	$CaCO_3$	Cu_2O	
CLB d1	79.995	10	10	0.005	1300
CLB d2	79.99	10	10	0.01	1300
CLB d3	79.98	10	10	0.02	1300
CLB d4	79.96	10	10	0.04	1300
CLB d5	79.94	10	10	0.06	1300
CLB d6	79.92	10	10	0.08	1300
CLB d7	79.9	10	10	0.1	1300

available at University Kebangsaan Malaysia (UKM). The exposed samples were kept in an opaque container at room temperature (25–32 °C) to prevent the photoluminescence effect of the background light. The reading was taken 24 hours after irradiation to allow for evacuation of shallow electron traps and avoid glow peaks at very low temperatures. The reader model 4500 Harshaw (USA) available at the Nuclear Laboratory, Departments Physics, Faculty of Science University Technology Malaysia (UTM) was used for the measurement of glow curves and other TL data.

3. Result and discussion

3.1. X-ray diffraction analysis

The X-ray diffraction (XRD) pattern of un-doped and Cu_2O doped calcium lithium borate glass is shown in Fig. 1, which indicates its amorphous structure, no sharp Bragg peaks are exhibited on any spectrum [1,2].

3.2. Thermoluminescence response of un-doped and Cu_2O doped (CLB) glass

CLB glass samples of the compositions listed in Table (1) were irradiated with ^{60}Co gamma-ray at a dose of 50 Gy. Fig. 2A and B shows the corresponding glow peaks and TL intensity of glow curve. The TL response (μC/g) varies with the sample composition. The higher TL response was observed for Sample (CLB2) and therefore, this sample was chosen to be doped with different Cu_2O concentrations according to that listed in Table (2). Fig. 3, illustrates the corresponding glow curves. The intensity (μA) of the glow curves of various concentrations of Cu_2O doped (CLB2) glass was seen to show the highest value for sample (CLB d3) or (0.02 mol %) Cu_2O. Fig. 4 illustrate the comparing between the TL intensity of glow curve for undoped (CLB2) and 0.02%Cu doped (CLBd2), where the TL intensity of Cu doped higher than the undoped.

3.3. Annealing procedure

The first process to be done is to anneal Cu_2O doped Calcium lithium borate (CLB) glasses, in order to get the highest sensitivity and to eliminate the effects of the previous irradiations [4]. The experiment was carried out using different annealing temperatures (annealing period was 30 min for each temperature).The temperatures used were 100, 200, 300, and 400 °C. After that, samples were exposed to 50 Gy under Cobalt-60 gamma irradiation and then readout Fig. 5 shows the TL emission at various annealing temperatures from 100 to 400 °C. Each experimental point was obtained by taking the average of five individual measurements. In the same figure the standard deviation in percentage (STD %) has been also plotted against the annealing temperature. It can be seen that the lowest standard deviation and the highest TL emission is obtained at 300 °C.To optimize the annealing time, the samples were annealed at a temperature of 300 °C and the annealing time was varied from 15 to 60 min. After annealing, the samples were exposed to 50 Gy of gamma irradiation and the readouts were carried out. The TL responses of each sample were read five times and the average TL response (μC/g) and standard deviation were calculated. Fig. 6 shows that the highest TL response was observed for an annealing time of 30 min.

3.4. Time temperature profile (TTP) setting

In this study the utilized (TTP) of the TLD reader was set

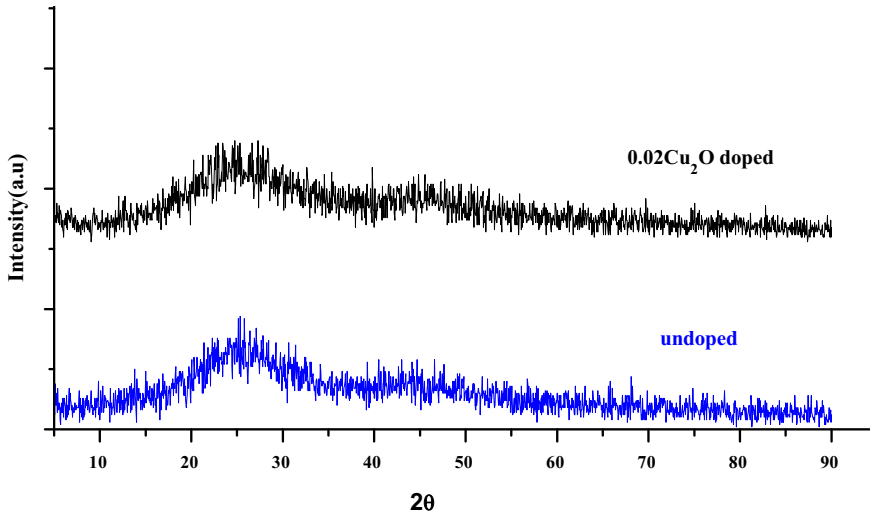

Fig. 1. XRD patterns of undoped and doped 0.02 mol%Cu2O calcium lithium borate glass.