Jurnal Teknologi

Full Paper

# THERMOLUMINESCENCE RESPONSE OF NANOPARTICLES GOLD DOPED LITHIUM BORATE GLASS SUBJECTED TO PHOTON IRRADIATION

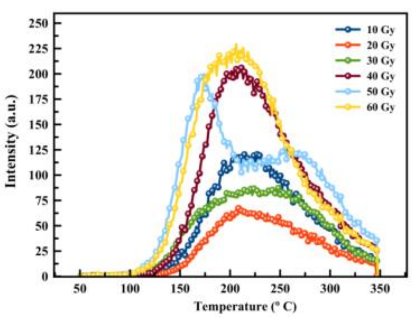
**Article history**
Received
*13 November 2014*
Received in revised form
*12 September 2015*
Accepted
*1 October 2015*

Haydar K. Obayes[a,b*], H. Wagiran[a], R. Hussin[a], M. A. Saeed[a], A. Saidu[b]

[a]Department of Physics Sciences, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia
[b]Department of Physics, Universiti of AL-Qadisiya, Iraq

*Corresponding author
hayder.physics1@gmail.com

## Graphical abstract




## Abstract

The absorption coefficient of Borates glass is much closed to human body tissue. This fact makes borates as an ideal material for thermoluminescence material either for medical or environmental application. In this study, a glass system of 15% Li2CO3+ 85% H3BO3 doped with 0.1mol %nano-gold was prepared by using melt-quenching technique. Undoped and Au doped lithium borate glass samples were exposed to Co-60 gamma ray (1.25 MeV) with various doses ranging from 10 to 60 Gy by using Gammacell 220 excel. Various TL properties such as TL glow curve, linearity and sensitivity of the prepared glass were investigated. From the TL glow curve, it was found that the TL intensity increased by addition of Au into the glass system. The TL intensity of Au doped glass increases about 23 times higher than the undoped glass. The study also shows that the doped borate glass has a linear response subjected to Co-60 gamma irradiation at doses ranging from 10 to 60 Gy. The sensitivity of doped glass is about 22 times higher compared to un-doped glass.

*Keywords:* Co-60 gamma, Thermoluminescence, X-ray diffraction, lithium borate, Au nanoparticles

## Abstrak

Pekali serapan kaca borat adalah hampir sama dengan tisu badan manusia. Perkara ini menjadikan kaca borat merupakan satu bahan yang ideal sebagai bahan luminesen terma sama ada untuk penggunaan perubatan atau alam sekitar. Dalam kajian ini sistem kaca15% Li2CO3+ 85% H3BO3 yang didopkan dengan zarah nano-emas (Au) telah disediakan dengan menggunakan teknik sepuh lindap Sampel kaca litium borat yang tidak didopkandan yang didopkan dengan Au didedahkan kepada sinar gama Co-60 (1.25 MeV) pada pelbagai dos dari 10 hingga 60 Gy menggunakan Gammacell 220 excel. Berbagai-bagai sifat luminesen terma seperti lengkung berbara luminesen terma, kelinearan dan kepekaan bagi sampel kaca yang disediakan telah disiasat. Daripada lengkung berbara luminesen terma, didapati keamatan luminesen terma bertambah dengan penambahan Au dalam sistem kacater sebut. Keamatan luminesen terma bertambah kira-kira 23 kali lebih tinggi daripada kaca yang tidak didopkan. Kajian ini juga menunjukkan kaca borat yang didopkan mempunyai sambutan yang linear bagi penyinaran sinargama Co-60 pada dos dalam julat 10 hingga 60 Gy. Kaca yang didopkan mempunyai kepekaan kira-kira 22 kali lebih tinggi berbanding dengan kaca yang tidak didopkan.

*Kata kunci*: gama Co-60, Luminesen terma, Belauansinar-X, litiumborat, Nano zarah Au

## 1.0 INTRODUCTION

Thermoluminescence (TL) is an ability of certain insulators to emit light upon thermal stimulation[1]. The intensity of the light emitted by some materials depends on the radiation dose received by the material[2], which makes these materials suitable as dosimeters. Thermoluminescence dosimetry (TLD) is a form of luminescence that is exhibited by certain crystalline materials, such as some minerals, when previously absorbed energy from electromagnetic radiation or other ionizing radiation is re-emitted as light upon heating of the material.

ATLD material used for dosimetry should be able to provide reliable reproducible dose readings, be highly sensitive, thermally and chemically stable and easy preparation [3]. Precise measurements are required in the study of TL materials [4].Borate glasses are very interesting amorphous materials by considering their specific structure and physical properties especially when the glass is doped by other materials such as gold (Au).Lithium borate is a white powder which has an indistinct order [5] and it has a melting point of 917 °C .It solubility is in a moderate range of 1-10% along with a density of 2.4 g/cm$^3$. Lithium borate processes numerous technological piezoelectricity [6] with a simple glow curve and easy annealing procedure. There are several important parameters that should be determined in order to introduce the reliable dosimeter. The most significant parameters are as follow; simple glow curve, dose linearity and sensitivity [7]. This study was an attempt to investigate the TL properties of Au-doped lithium borate glass in order to identify the capability of this glass to be considered as TLD.

## 2.0 EXPERIMENTAL

This study undoped and Au-doped lithium borate glasses were prepared with the composition of 85 % mol $H_3BO_3$+ 15 %mol $Li_2CO_3$ (as undoped) and 85 % mol $H_3BO_3$+ 15 %mol $Li_2CO_3$+ 0.1 % mol Au (as doped). Lithium carbonate in form of powders and boric acid were mixed and homogenized by milling them for 30 minutes. The samples were melted in an alumina crucible at 1100 ° C for 1 hour in an electrical muffle furnace. The molten samples were poured into a steel plate and placed in another furnace for further annealing at a temperature of 300°C for 10 hours. The samples were then cooled inside the furnace until it reached the room temperature to avoid thermal stress. X-ray powder diffraction analysis was performed using Siemens Diffractometer D5000 system at the room temperature on the glass samples to confirm their amorphous structure. Subsequently, γ-ray photons (60Co) provided by Gammacell 220 excel at Malaysia were used to irradiate the glass samples over a dose range 10-60 Gy. The TL responses were read out by using Harshaw TLD Reader 4500 at Department of Physics, Faculty of Science, UTM.

## 3.0 RESULTS AND DISCUSSION

### 3.1 X-Ray Diffraction (XRD) Analysis

The prepared samples were analyzed using X-ray diffraction (XRD) in order to study the structure of the glass. In this experiment, XRD technique was employed for undoped and Au doped samples. The measurements were carried out using Siemens Diffractometer D5000 system at the room temperature with a scanning rate of 0.05 o/sec. The results confirm the amorphous structure of the glasses since there are broad peaks appeared instead of sharp peaks on the spectra pattern as shown in Figure 1.

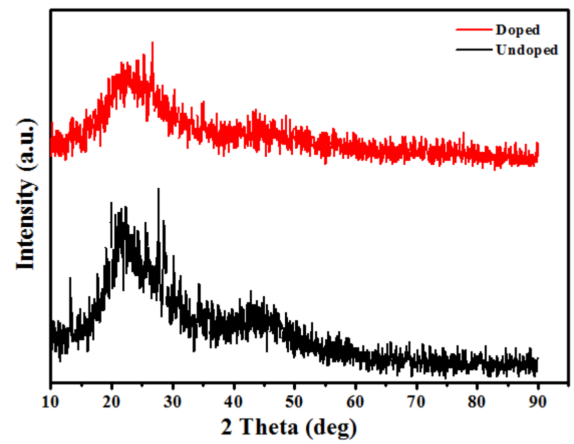



**Figure 1** XRD pattern of undoped and Au-doped glass sample

### 3.2 TL Glow Curve

Thermoluminescence light emission which is known as the thermoluminescence glow curve is defined as the intensity of luminescence as a function of temperature, which is possible to exhibit several maxima [8].This glow curve varies with the mode of heating and heating temperature. The area under the curve represents the radiation energy deposited. Figure 2 and Figure 3 show the glow curves of undoped and Au-doped lithium borate glass, respectively. It can be seen that doped glass gives better glow curve than the undoped lithium borate glass. The TL response of doped and undoped glass were 645 nC g$^{-1}$ and 30 nCg$^{-1}$ respectively. The TL response of Au-doped lithium borate was found about 21 times higher than undoped glass. On the other hand, the glow curve was shifted from 213 ° C to 186 ° C with the addition of Au this shift to low temperature with high intensity. This behavior indicated that the gold create new traps and defect with glass host which is completely different from undoped glass.

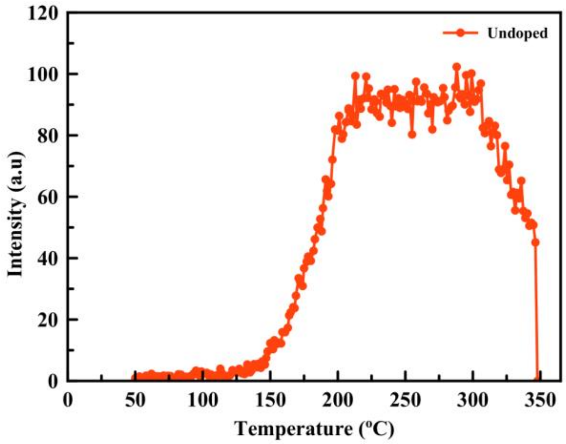



**Figure 2** The glow curve of undoped lithium borate glass exposed to 10 Gy Co-60 gamma irradiation

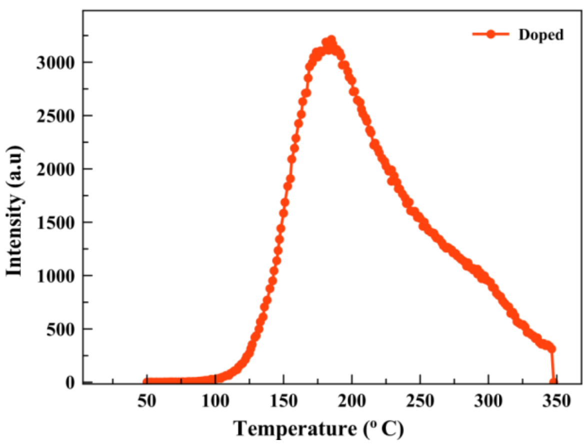



**Figure 3** The glow curve of Au-doped lithium borate glass exposed to 10 Gy Co-60 gamma irradiation

Figure 4 and Figure 5 show the glow curve of the undoped and Au-doped lithium borate samples for different doses, respectively. It can be seen from both figures that the addition of Au in the borate compound enhanced the TL response of the material. It was also found that the TL response increases with the increasing delivered dose.

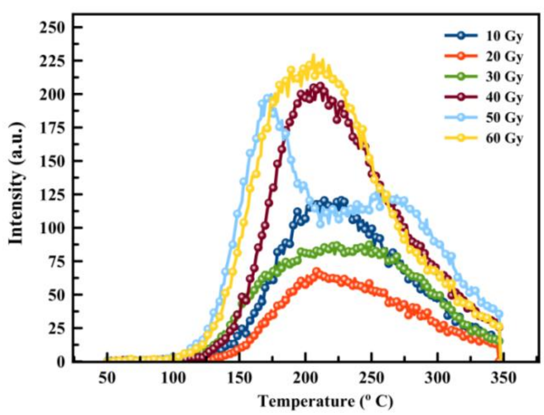



**Figure 4** The glow curve of undoped lithium borate glass exposed to different doses of Co-60 gamma irradiation

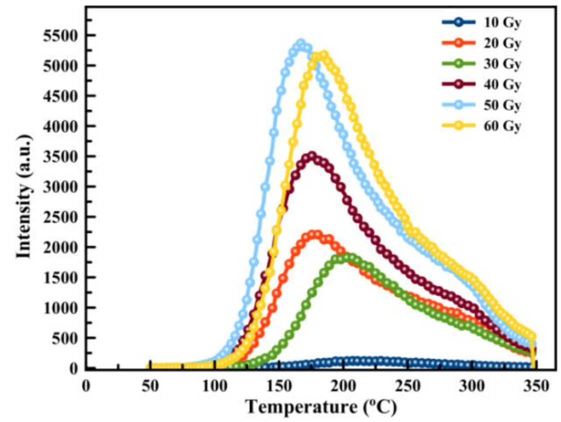



**Figure 5** The glow curve of Au-doped lithium borate glass exposed to different doses of Co-60 gamma irradiation

### 3.3 TL Response-Dose Relationships

A linear relationship between TL response and the absorbed dose is very important characteristic for any thermoluminescence dosimetric application [9, 10]. For many applications, it is commonly favored to have a linear dose TL signal relationship. In this work, the TL response of undoped and Au-doped lithium borate glasses were investigated over gamma doses in the range 10 to 60 Gy. The results are presented in Table 1 for both samples and plotted as shown in Figure 6. Each data point represents the average of the three individual sample readings.

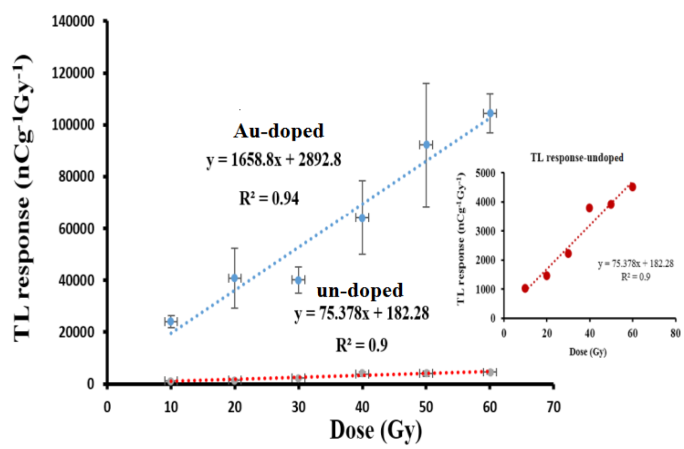



**Figure 6** The TL response of undoped and Au-doped lithuim borate glass subjected to Co-60gamma ray versus dose.The right hand sideof the figure was expanded for easy viewing

**Table 1** TL yield for 1.25 MeV photon radiations for the undoped and Au-doped lithium borate glass of various doses

| Dose (Gy) | TL response of undoped nC g-1 | TL response of doped nC g-1 |
|---|---|---|
| **10** | 1023±81 | 24054±2272 |
| **20** | 1459±263 | 40752±11662 |
| **30** | 2220±312 | 40098±4984 |
| **40** | 3791±751 | 64104±14161 |
| **50** | 3914±906 | 92182±23925 |
| **60** | 4513±770 | 104512±7535 |

As can be seen from Figure 6, which combines the relationship between delivered dose and the TL response of both undoped and Au-doped lithium borate glasses, a linear response to the Co-60 gamma radiation at dose range 10 to 60 Gy was exhibited. The dose response of Au-doped lithium borate glass samples show better behavior and always have higher response than that of undoped lithium borate glass. A regression coefficient (R2) is another indication for good linearity. From Figure 5, the R2 values for Au-doped are 0.94 and 0.9 for undoped sample. This indicates the occurrence of a little scatter in the TL values at this dose range. The R2 value is a measure of how well the data correlate. The R2 value obtained for Au-doped is closed to one.

### 3.4 Sensitivity

The sensitivity of a TL material is another important characteristic of dosimetry material [11, 12]. The TL sensitivity is expressed as glow curve area per unit mass of dosimeter and per unit dose (nCg-1Gy-1). The TL sensitivity can be calculated from the slope of graph TL response versus dose as in Figure 6. It was found that the sensitivity of undoped and doped samples are 75.38 nC $g^{-1}$ $Gy^{-1}$ and 1658.8 nC $g^{-1}$ $Gy^{-1}$ respectively. The sensitivity of Au-doped glass is shown to be 22 times higher than that of the undoped glass subjected to Co-60 gamma ray at dose range 10 – 60 Gy.

## 4.0 CONCLUSIONS

Glass samples of undoped and Au-doped lithium borate were prepared by the melt quenching method. TL dosimetric properties of undoped and Au (0.1 mol %) doped glasses were investigated. It was found that Au-doped lithium borate glass shows higher thermoluminescence response compared to undoped sample. The TL response of the Au-doped glass was about 23 times higher than the undoped sample. Both glasses show a linear TL-dose relationship with regression coefficient (R2) of 0.9466 for doped sample and 0.952 for undoped sample. The sensitivity of Au-doped lithium borate glass was found to be about 22 times higher than undoped glass sample.this optiend glass recommended to using as TLD.

## Acknowledgement

The author(s) would like to thank the Malaysian Ministry of Education (MOE) and Universiti Teknologi Malaysia for providing the financial support and facilities for this study

## References

[1] Aboud, H., Wagiran, H., Hussin, R., Ali, H., Alajerami, Y., Saeed, M. 2014. Thermoluminescence Properties of the Cu-Doped Lithium Potassium Borate Glass. *Applied Radiation and Isotopes.* 90: 35-9.

[2] Mattem, P., Watkins, L., Skoog, C., Brandon, J., Barsis, E. 1974. The Effects of Radiation on the Absorption and Luminescence of Fiber Optic Waveguides and Materials. Nuclear Science. *IEEE Transactions on*. 21: 81-95.

[3] McKeever, S., Moscovitch, M. 2003. Topics under Debate-on the Advantages and Disadvantages of Optically Stimulated Luminescence Dosimetry and Thermoluminescence Dosimetry. *Radiation Protection Dosimetry.* 104: 263-70.

[4] Mejdahl V, Bøtter-Jensen L. 1994. Luminescence Dating of Archaeological Materials Using a New Technique Based on Single Aliquot Measurements. *Quaternary Science Reviews.* 13: 551-4.

[5] Weymann, G. W. Lithium and Its Known Compounds: An Inaug. diss1855.

[6] Damjanovic, D. 1998. Materials for High Temperature Piezoelectric Transducers. *Current Opinion in Solid State and Materials Science.* 3: 469-73.

[7] Ege, A. T., Ekdal, E., Karali, T., Can, N., Prokić, M. 2007. Effect of Heating Rate on Kinetic Parameters of β-irradiated Li2B4O7: Cu, Ag, P in TSL measurements. *Measurement Science and Technology.* 18: 889.

[8] Bos, A. J. J. 2001. High Sensitivity Thermoluminescence Dosimetry. *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms*. 184(1): 3-28.

[9] Pradhan, A. 1981. Thermoluminescence Dosimetry and Its Applications. *Radiation Protection Dosimetry*. 1: 153-67.

[10] Furetta, C., Kitis, G., Weng, P., Chu, T. 1999. Thermoluminescence characteristics of MgB4O7: Dy, Na. Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment. 420: 441-5.

[11] Zha, Z., Wang, S., Shen, W., Zhu, J., Cai, G. 1993. Preparation and Characteristics of LiF: Mg, Cu, P Thermoluminescent Material. *Radiation Protection Dosimetry*. 47: 111-8.

[12] Furetta, C., Prokic, M., Salamon, R., Prokic, V., Kitis, G. 2001. Dosimetric Characteristics of Tissue Equivalent Thermoluminescent Solid TL Detectors Based on Lithium Borate. *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment*. 456: 411-7.