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# Thermoluminescence characteristics of $C^{6+}$ ion beam - irradiated $Li_6Gd(BO_3)_3:Dy^{3+}$ phosphor

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## ABSTRACT

The present paper reports the thermoluminescence (TL) behaviour of Li6Gd(BO3)3:Dy3+phosphor on exposure to carbon ion beam. The phosphor was synthesized by combustion technique with varying Dy3+concentrations. The TL glow curve of the phosphor, consist of prominent and well defined TL peaks at 131oC and 228oC for carbon ion fluence of 5 x 1010 ions/cm2. Nature and peak position remains stable for different activator concentrations and fluence, however change is noticed in TL intensity. TL intensity is found maximum for Dy3+ concentration of 0.1 mole% at the fluence of 5 x 1010ions/cm2. This TL curve was analyzed by Glow curve deconvolution (GCD) functions. Activation energy (E), order of kinetics (b) and frequency factor (s) were determined using Chen's peak shape method and theoretical curve was drawn using GCD functions.

**Keywords:** Li6Gd(BO3)3:Dy3+, carbon ion irradiation, thermoluminescence, borates.

## I. INTRODUCTION

Radiation therapy is playing an important role, world-wide, in the treatment of cancer. Conventional cancer radiation therapy, make use of different kinds of ionizing radiations like x-rays, gamma rays etc for the treatment of tumors. These radiations destroy the tumor, but cause harm even to the DNA of surrounding healthy cells. So, in order to save the surrounding healthy tissues, lethal dose could not be administered to cancerous cells. Thus it necessitates proper targeting and accurate dose delivery for destroying tumor, adjacent to vital body parts (1).

Heavy particle beam of carbon ions are successful in the precise targeting of harmful tumor due to their slight spatial scattering, thereby, reducing the irradiation of normal tissues in the vicinity. Carbon ions are found to deposit a minimal dose near the surface and maximum at the end of its range. The peak thus formed is called as Bragg peak. As the Bragg maximum is narrow and sharp, the beam is scattered using ridge filter and spread over an area sufficient to create, spread out Bragg peak (SOBP) to match shape and size of the tumor (2). Increased relative biological effectiveness (RBE) helps deep penetration of carbon ions for effective destruction of radio resistant tumors too (3). However, finalizing a particular dose for treatment depends on dosimetry. These dosimetric measurements reflect the major features of the beam which proves beneficial in deciding the future treatment, dose planning and deliverance. In short, the dosimetry offers important information regarding quality, quantity and the distribution of dose released by the beam (4). Thermoluminescence is a well-known method for the radiation dosimetry of ionizing radiations (5).

The present phosphor has been studied, so as to look into its potential for TL dosimetry for $C^{6+}$ ion beam irradiation.

## II. EXPERIMENTAL

The present $Li_6Gd(BO_3)_3:Dy^{3+}$ phosphor was prepared by combustion synthesis using $LiNO_3$, $Gd(NO_3)_3$, $Dy(NO_3)_3$, as starting materials $H_3BO_3$ as flux and urea $NH_2CONH_2$ as a fuel for combustion. Pellets of the synthesized powder phosphor were made and irradiated by a $C^{6+}$ ion beam of 75 MeV. The beam with current of 0.5 pnA, was generated by a 16 MV tandem van de Graff type Electrostatic Accelerator (15 UD Pelletron) at the Inter-University Accelerator Center (IUAC), New Delhi, India (6). The phosphor was further investigated for different $C^{6+}$ ion beam fluences in the range of $2 \times 10^{10} – 1 \times 10^{12}$ ion $cm^{-2}$, at room temperature. After the required exposure, TL measurements were performed with Harshaw 3500 TL reader. TL emission spectra was recorded using 5mg of irradiated phosphor every time, at a linear heating rate of $5^{o}C/s$, in an open atmosphere.

## III. THERMOLUMINESCENCE STUDY OF THE PHOSPHOR

The TL glow curves of $C^{6+}$ ion beam irradiated $Li_6Gd(BO_3)_3:Dy^{3+}$ consists of two prominent and well defined peaks at $131^{o}C$ and $228\,^{o}C$ due to two different kind of traps as seen in Figure 1. The nature and position of the peaks remains unchanged even for different Dy concentration for the fluence of 5 x $10^{10}$ ions/$cm^2$ .The low temperature peak at $131^{o}C$ is due to the formation of shallow traps whereas the high temperature peak at $228^{o}C$ is formed by deeper traps. The glow curve structure possesses TL high temperature peak needed for an efficient TL dosimeter. The intensity of peaks increase initially with the increase in dopant concentration and is found maximum for 0.1 mole %. It reflects that, present phosphor with Dy 0.1mole% is most sensitive from the series. Subsequent increase in the dopant concentration quenches the luminescence. Thus, the dopant concentration plays an important role in deciding the TL intensity of a phosphor.

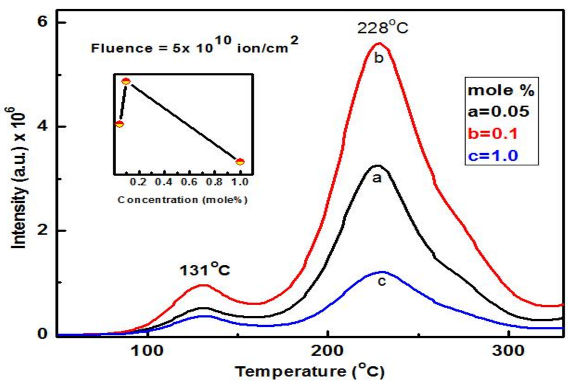


**Figure 1.** TL glow curves of $C^{6+}$ ion beam irradiated $Li_6Gd(BO_3)_3:Dy^{3+}$ phosphor for a fluence of 5 x $10^{10}$ ions/$cm^2$ for three different Dy concentration

TL glow curves of $C^{6+}$ ion beam irradiated $Li_6Y(BO_3)_3:Dy^{3+}$ phosphor for different fluence can be seen in Figure 2.TL intensity is maximum for the fluence of 5 x $10^{10}$ ions/$cm^2$ and decreases with subsequent increase in fluence. Nature and peak position of glow curve remains unchanged indicating that the phosphor comprises of similar traps and is stable even at high fluence. But, greater ion fluences saturate the TL traps and prevent the exploitation of electrons for recombination and reduce the TL intensity as seen in Figure 2.

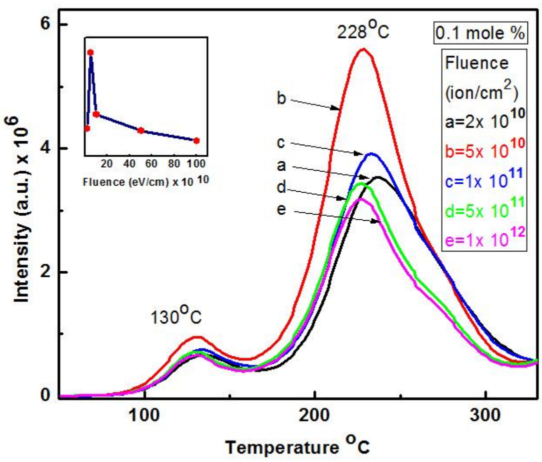


**Figure 2.** TL glow curves of $Li_6Gd(BO_3)_3:Dy^{3+}$ phosphor for different fluence of $C^{6+}$ ion ion beam irradiation

TL glow curve for $Li_6Gd(BO_3)_3:Dy^{3+}$ ( 0.1mole% ) phosphor for fluence of 5 x $10^{10}$ ions/$cm^2$ was analysed using Chen's peak shape method. The Glow Curve Deconvolution was carried out for this glow curve using Kitis equation (7) based on the experimentally determined maximum TL intensity $I_M$ and corresponding temperature $T_M$ given below

$$I(T)=I_M b^{b-1} \exp\left(\frac{E}{kT} \times \frac{T-T_M}{T_M}\right) \times$$

$$\left[(b-1)\frac{T^2}{T_M{}^2}\left(1-\frac{2kT}{E}\right)\exp\left(\frac{E}{kT} \times \frac{T-T_M}{T_M}\right)+1+(b-1)\frac{2kT_M}{E}\right]^{-\frac{b}{b-1}}$$

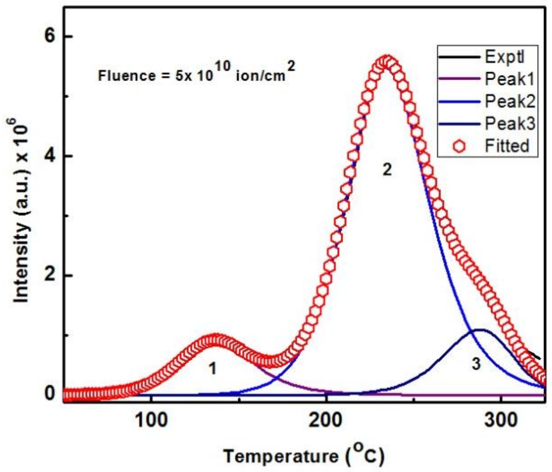


**Figure 3.** Glow Curve Deconvolution of TL glow curve for $Li_6Gd(BO_3)_3:Dy^{3+}$ ( 0.1mole% ) phosphor for fluence of 5 x $10^{10}$ ions/$cm^2$

Figure 3 displays the Glow curve deconvolution of $Li_6Gd(BO_3)_3:Dy^{3+}$ ( 0.1mole% ) phosphor for fluence of 5 x $10^{10}$ ions/$cm^2$ **.**The glow curve consists of 3 peaks whose kinetic parameters are given in table1. Higher activation energy for the peaks indicate that the energy from irradiation could be retained for a long time , which is a requisite trait for an efficient dosimeter. The peaks at 136 °C and 233 °C follow second order kinetic, while the peak at 288°C follows general order. A fitting was obtained among the experimental and theoretical values with figure of merit equal to 4.07.

**Table 1.** Kinetic Parameters of deconvoluted peaks calculated by Chen's method for $Li_6Gd(BO_3)_3:Dy^{3+}$ phosphor irradiated with $C^{6+}$ ion beam of fluence 5 x $10^{10}$ ions/$cm^2$

| Peaks | Kinetic Parameters | | | | | |
|---|---|---|---|---|---|---|
| | $T_M$ (°C) | $I_M$ | μ | E (eV) | b | s ($s^{-1}$) |
| Peak1 | 136 | 907500.8 | 0.52 | 0.960 | 2 | 9.27 x $10^{10}$ |
| Peak2 | 233 | 5.49 x $10^6$ | 0.52 | 1.310 | 2 | 6.14 x $10^{12}$ |
| Peak3 | 288 | 1.09 x $10^6$ | 0.47 | 1.511 | 1.4 | 1.05 x $10^{13}$ |

## IV. CONCLUSION

TL response of the phosphor depicts a stable high temperature peak at 228 °C favorable for retaining the dose from high energy carbon beam irradiation for a considerable time and this may prove useful for radiation dosimetry.

## V. ACKNOWLEDGEMENTS

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## VI. REFERENCES


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