# Feasibility Studies of EU+LI Co-Doped $GD_2O_3$ as a Thermo Luminescence Detector for UV Emission

**Hristo Y. Hristov, Valentin L. Velev, Nikolay M. Uzunov**

***Abstract.*** ***We have already studied the possibility to apply some sintered crystals such as $ZrO_2$ doped with Er and Li as appropriate detectors for ultra-violet (UV) light. The detection of the (UV) irradiation exploits the thermoluminescence (TL) emission of some crystals (phosphors) after being exposed to W irradiation with wavelength in the interval of 280nm - 360nm. It turned out that such crystals are easy to create and their TL glow cuvres possess well-shaped peaks with sufficient statistical data. In this article we present the results of our research toward the creation of netu sintered crystals, sensible to the W emission. Analysis of the thermoluminescence properties of Gd,O3, doped with Eu and Li has been conducted. Different quantities of lithium co-dopant have been added as $Li_2CO_3$ to a mixture of $Gd_2O_3$ with 10 wt% $Eu_2O_3$. Pellets sintered at a temperature of $1000^{0C}$ have been prepared and the kinetic parameters of the phosphors have been studied after irradiation with W light from a XBO lamp. It has been shown that the addition of 16 wt% $Li_2CO_3$of to the mixture of $Gd_2O_3$ with 10% $Eu_2O_3$ yields a maximum intensity of the peaks at $87^{0C}$ and at $145^{0C}$. Spectral emission and spectral sensitivity of the phosphors have been studied. The analysis applied to TL glow curves, obtained from the UV irradiated phosphors and kept after the irradiation at different times in a dark storage, revealed that the peaks have and relatively long fading. Analysis of the thermoluminescence properties of the phosphors obtained from $Gd_2O_3$, doped with Eu and Li, shows that the possess a good sensitivity to the UV emission and could be used for quantitative measurements of UV light.***

***Keywords:*** ***thermoluminescence, UV irradiation, UV detector , fading, glow curves***

## I. INTRODUCTION

Thermally stimulated luminescence (thermoluminescence) is a process of a release of luminescence light from crystals that have been primarily exposed to radiation. The plots of the light intensity with respect to the temperature, emitted during the linear heating of the crystals, are called “glow curves” and have complex shape, compounded by superimposed thermoluminescence peaks. The intensity of these peaks is as a rule linearly correlated to the quantity of radiation absorbed by the crystal and is largely exploited at present for applications in dosimetry, in nuclear medicine, in archaeology in environmental studies, etc. It has been observed that thermoluminescence (TL) emission of some materials can be induced also by irradiation with photons with “softer” than the X-rays’ and gamma-rays’ energy: the ultraviolet (UV) and the visible light.

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An important factor for the enhancement of the emission of the TL materials (phosphors) is the presence of lithium ions in the matrix, creating thus the presence of traps in the band gap. Co-doping with lithium is shown for a number of materials [1,2]. It is shown also, that sintered materials from $Zr0_2$ doped

## II. ENPERIMENTAL

### *A. Materials*

To obtain the TL materials sensible to the UV emission we have applied a simple sinterization procedure, similar to the one described in [4]. UV sensible phosphors have been made from sintered pellets of $Gd_20_3$ doped with 10% $Eu_20_3$. Quantities of Li have been added as $Li_2C0_3$, obtaining thus a set of samples with the following quantities of Li: 10%; 12%, 14%; 16% and 18%. The mixtures have been pressed in pellets with a diameter of 8mm and a thickness of about 1 mm using 5 ton press. Finally the pellets have been sintered at $1000^{0C}$ for 8 hours.

### *B. Methods*

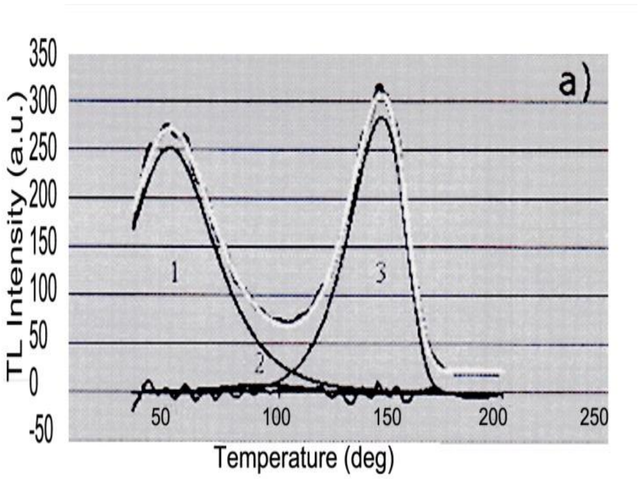
A setup for precise TL measurements (TL reader) developed in the Laboratory for nuclear physics and radioecology (LNPR) at the University of Shumen has been used to obtain the glow curves of the phosphors [5]. The system consists of a setup for sample heating, a glow curve measuring device on the basis of photo-multiplier tube, and a setup for sample irradiation with higher-intensity ultraviolet (UV) light. The operation and control of the system has been realized on the basis of PIC16F876 microcontroller as well as on original forward/backward feedback method, based on the so-called model predictive controllers, in order to achieve higher temperature stability and repeatability of the analyses conducted. Trap parameters of the phosphors have been studied using initial irradiation with ultraviolet light from a xenon short-arc lamp type XBO 75 W/2 from OSRAM. The crystals have been placed at a distance of 10 cm and the time of irradiation was 5 min. The fading of the peaks in the TL glow curve (GC) has been obtained calculating the intensity of the corresponding partial TL emission (the net peak area) from the phosphors, kept for a certain time after the irradiation in a dark storage at a temperature of 20°C. Glow curves, obtained with the TL reader, have been analyzed using a developed in the LNPR computer program implementing data smoothing using a Savitzky-Golay filtering and subsequently applying a minimization procedure based on conjugated gradients method for the TL peak decomposition technique.

## III. RESOLTS AND DISCUSSION

Glow curves of $Gd_20_3$, doped with 10% of $Eu_20_3$ and co-doped with different quantities of Li from $Li_2C0_3$ have been obtained measuring the TL emission immediately after 5 minutes of irradiation with UV without annealing. The GC, presented with a thick black line in figure 1, has been obtained at a heating rate of 0.16 °/s. Three peaks have been revealed by the decomposition analysis of the glow curves in figure 1: peak 1 at 47 °C, peak 2 at 87 °C and peak 3 at 145 °C, indicated as 1, 2 and 3 respectively. The resulting fit is presented with white line, overlapping the experimental values of the GC in the same figures. A plot of the peak intensities (integrated counts in the corresponding peak areas from fig. la) to fig. ie)) as a function of the quantity of Li co-dopant is shown in figure 2. The calculated kinetic parameters for the peaks appearing in the TL glow curves of $Gd_20_3$ co- doped with Eu and Li from $Eu_2O_3$ and $Li_2CO_3$ are shown in Table 1.

## IV. CONCLUSION

Quantitative assessment of the fading of the three peaks from the GC shown in figure 1 reveals that the low-temperature peak 1 fades rapidly in few hours. Peaks 2 and 3 from the GC have sufficient fading allowing quantitative TL measurements within a couple of days. Both peaks possess higher excitation energy and relatively good count-rate statistics. Phosphors from from $Gd_20_3$, co-doped with Eu and Li were irradiated with gamma rays from cobalt source in the energy range of 1.1MeV – 1.3MeV. It turned out that the material did not show statistically significant excitation even under of gamma-ray doses up to several Sieverts. Quantitative assessment about the spectral sensitivity of the $Gd_20_3$, co-doped with 10% of Eu and 16% of Li showed that the material possess a sensitivity for UV light with a wavelength in the interval of 28onm - 42onm. We also compared the TL yield of $Gd_20_3$ co-doped with 10% of Eu and 16% of Li with respect to the TL yield of $Zr0_2$ co-doped with 1% Er and 8% of Li. According out previous research, the quantities of Er and Li in the last sample proved to be the best combination for $Zr0_2$ based TL materials [5]. The excitation of both samples was carried out using excitation with XBO lamp at equal other excitation conditions such as time of irradiation and source-to- detector distance. It was shown that the material from $Gd_20_3$, co-doped with 10% of Eu and 16% of Li possess higher TL yield. This fact and the relatively slow fading of peaks 2 and 3 suggest a reasonable opportunity to exploit such a material as a potential phosphor for short-term UV measurements.



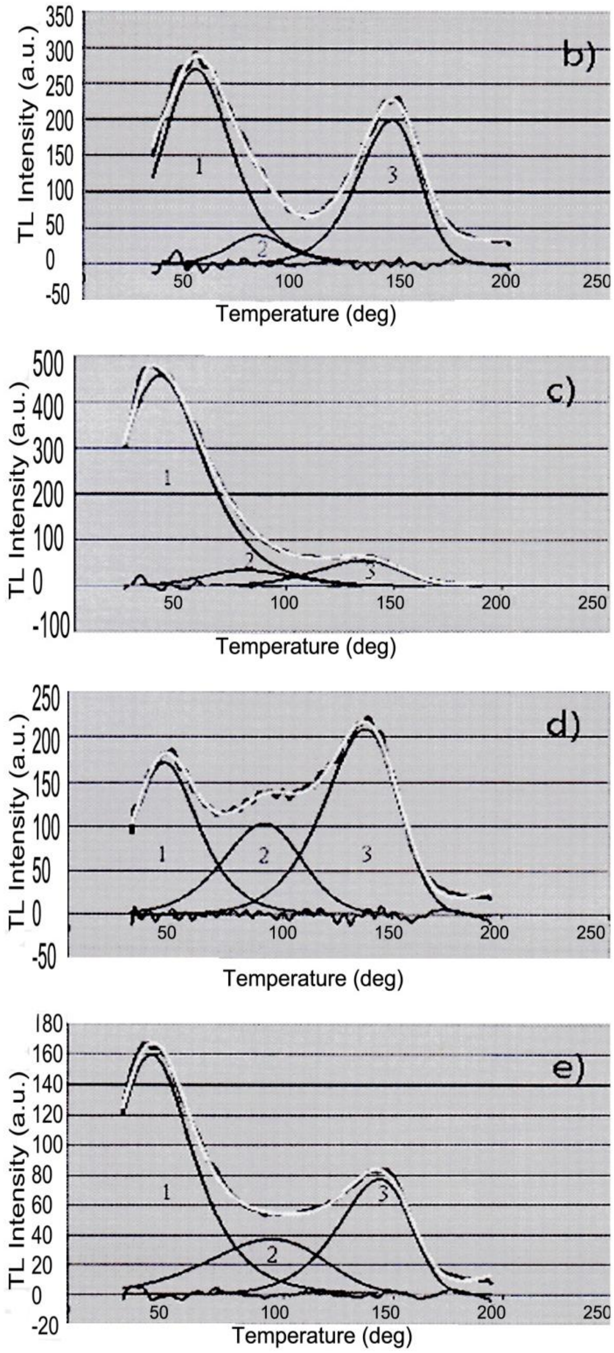




**Fig. 1 Glow curves of $Gd_2O_3$ doped with 10wt% of $Eu_2O_3$ obtained after irradiation with UW light. The material is codoped with: a) 10% Li from $Li_2CO_3$; b) 12% Li from $Li_2CO_3$; c)14% Li from $Li_2CO_3$:; d) 16% Li from $Li_2CO_3$; e) 18% Li from $Li_2CO_3$**

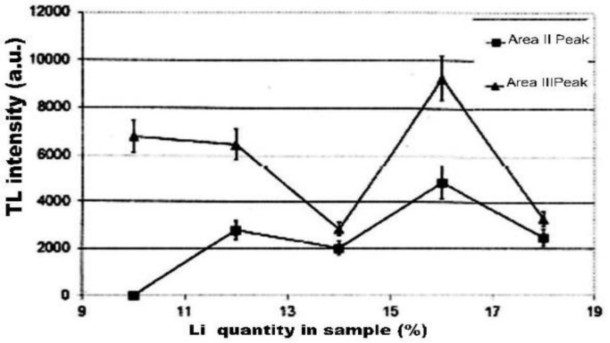



**Fig. 2 TL emission of the sintered $Gd_2O_3$ doped with10 wt% of Eu as a function of the quantity of Li co-dopand**

**Table 1 Kinetic parameters of the peaks revealed in TL glow curves of $Gd_2O_3$ co-doped with Eu and Li**

| Peak reference | Maximum temperature position (°C) | Activation energy (eV) | Kinetic order |
|---|---|---|---|
| I | 47 ± 2 | 0.6 ± 0.2 | 2.0 – 0.1 |
| II | 87 ± 2 | 0.7 ± 0.1 | 1.8 ± 0.1 |
| III | 145 ± 1 | 1.1 ± 0.08 | 1.2 ± 0.1 |

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