JOURNAL OF OPTOELECTRONICS AND ADVANCED MATERIALS Vol. 12, No. 4, April 2010, p. 892 - 894

Influence of lithium co-dopant on the UV-stimulated thermoluminescence of Erbium-doped zirconium dioxide

H. HRISTOV[a], N. ARHANGELOVA[a], I. PENEV[b], M. BELLO[c], G. MOSCHINI[c], N. UZUNOV[a,c*]
[a]*Shumen University Konstantin Preslavsky,115 Universitetska street, 9712 Shumen, Bulgaria,*
[b]*Institute for Nuclear Research and Nuclear Energy, BAS, 72 Tzarigradsko chaussee Blv, 1784 Sofia*
[c]*National Laboratories of Legnaro, INFN, Viale dell'Universita 2, 35020 Legnaro, Italy*

Research for thermoluminescence (TL) phosphors possessing a good sensitivity for the ultraviolet light (UV) and relatively long fading has been conducted. Kinetic parameters of ZrO_2 doped by Eu and Li have been studied as a potential phosphor sensible to the UV light. Quantities of lithium co-dopant were added as Li_2CO_3 to a mixture of ZrO_2 doped with 1% Er_2O_3. Pellets sintered at a temperature of 1200^0C were irradiated with UV light. The analysis applied to the thermoluminescence glow curves of these phosphors revealed that the addition of Li enhances the TL emission of peaks at 65^0C and at 105^0C. The latter showed up good sensitivity to the UV emission, has a relatively long fading and could be a convenient peak for detection and measurements of UV light.

(Received April 7, 2010; accepted April 26, 2010)

Keywords: Thermoluminescence, Glow curve, Kinetic order, Activation energy, Fading

1. Introduction

Thermally stimulated luminescence (thermo-luminescence) of crystals exposed to radiation is largely exploited at present in many applications: in dosimetry; in nuclear medicine; in environmental studies; in archaeology, etc. Thermoluminescence (TL) emission of some crystals is caused also after irradiation with photons with "softer" than the X-rays' and gamma-rays' energy, say with the ultraviolet (UV) and visible light.

The enhancement of the TL emission of some phosphors after co-doping with lithium has been shown for a number of materials [1,2]. In this article we present the results from the analysis of the TL emission of ZrO_2 doped with Eu and Li as a potential indicator sensible to the ultraviolet light in the range of 290 nm—400 nm. The TL emission from the sintered crystals has been studied as a function of the quantity of Li co-dopant and the kinetic parameters for the peaks appearing in the TL glow curve have been obtained.

2. Experimental

2.1. Materials

For the purposes of the detection and registration of ultraviolet light using the thermoluminescence (TL) of specific phosphors we have applied a technology similar to the one described in [3]. UV sensible phosphors have been made from sintered pellets of ZrO_2 doped with 1% Er_2O_3.

The quantities of Li have been added as Li_2CO_3 thus obtaining samples with the following concentrations of Li: 2.5%; 5%; 10% and 15%. The mixtures have been pressed in pellets with a diameter of 8mm and thickness of 1 mm using a 5 ton press. Finally the pellets have been sintered at 1200 ^{o}C for 8 hours.

2.2. 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 [4].

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.

3. Results and discussion

A typical TL glow curve (GC) of ZrO_2 doped only with Er_2O_3 and measured immediately after the irradiation with UV light is shown in Fig. 1. The GC presented with a thick black line has been obtained without annealing at a heating rate of 0.16 ^{0}/s. Three peaks have been revealed by the decomposition analysis: peak 1 at 65^0C, peak 2 at 105^0C and peak 3 at 150^0C. The resulting fit is presented with white line in the same figure.

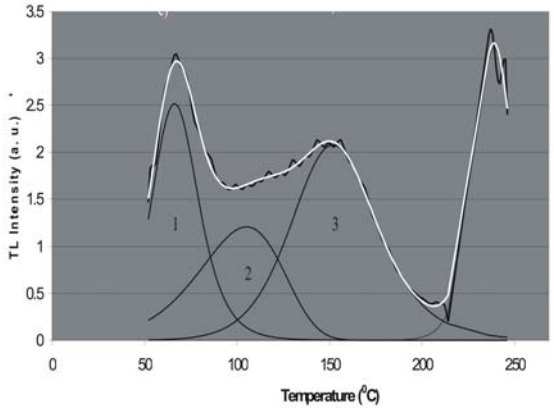

Fig.1. TL glow curve of ZrO_2 doped with 1% Er_2O_3 obtained immediately after irradiation with UV light.

The TL glow curves obtained from ZrO_2 doped with Er_2O_3 and with the four quantities of Li_2CO_3 measured immediately after the irradiation with UV light are shown in figure 2. The glow curves presented with thick black lines have been obtained without annealing at a heating rate of 0.16 ^{0}/s. The same three peaks at 65^{0}C, at 105^{0}C and at 150^{0}C similarly as in the undoped with lithium TL glow curve have been revealed by the decomposition analysis. The resulting fit (figure of merit for all fits was less than 3%) is presented with white line in the figures.

Table 1. Kinetic parameters of the peaks revealed in ZrO_2 doped with Er_2O_3 and Li_2CO_3.

Peak reference	Maximum temperature position (^{0}C)	Activation energy (eV)	Kinetic order
I	65 ± 2.0	0.52 ± 0.07	1.1 ± 0.15
II	105 ± 1.8	0.96 ± 0.03	1.6 ± 0.29
III	150 ± 1.3	1.03 ± 0.06	2.0 – 0.02

The calculated kinetic parameters for the peaks appearing in the TL glow curves of ZrO_2 doped with Er_2O_3 and Li_2CO_3 are shown in Table 1.

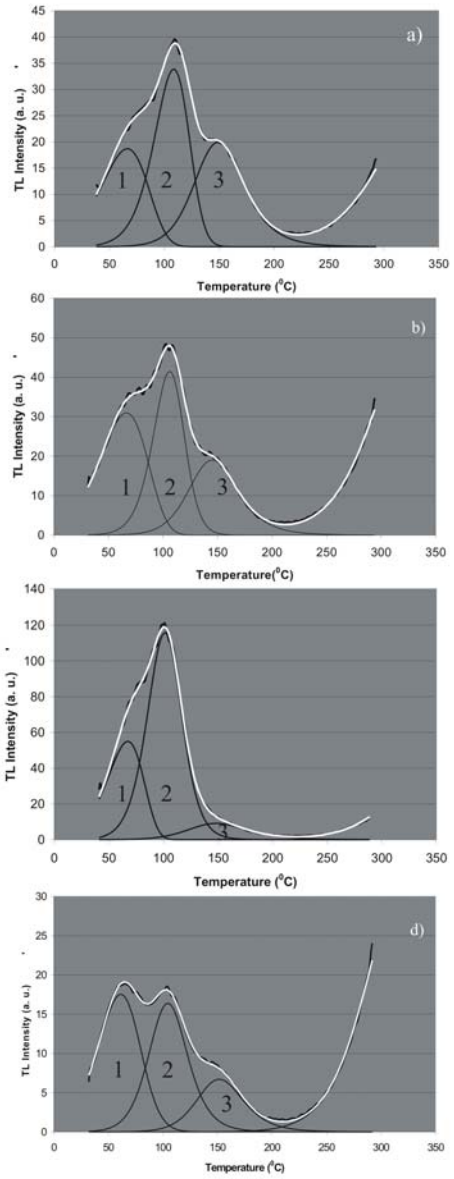

Fig. 2. Glow curves of ZrO_2 doped with 1% Er_2O_3 obtained after irradiation with UV light: a) doped with 2.5% Li_2CO_3; b) doped with 5% Li_2CO_3; c) doped with 10% Li_2CO_3; 9) doped with 15% Li_2CO_3.

A plot of the peak intensities (integrated counts in the corresponding peak areas from fig 2a) – 2c)) as a function of the quantity of Li co-dopant is shown in figure 3.

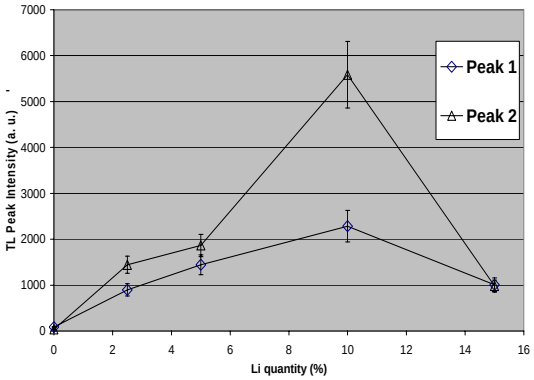

Fig. 3. TL emission from the sintered ZrO_2 doped with Er_2O_3 crystals as a function of the quantity of Li co-dopant.

4. Conclusions

The analysis of the TL glow curves of the sintered crystals shows that the presence of Li ions as a co-dopant enhances significantly the low-temperature TL emission of ZrO_2 doped with Er_2O_3 with respect to the UV light. From the plotted data shown in figure 3 is clear that quantities between 8% and 10% of Li_2CO_3 induce higher thermoluminescence emission of the peaks at 105 ^oC and 65 ^oC.

As it has been observed in [2] the increase of the TL emission of the two peaks is followed by the decrease of the higher-temperature TL peaks where the deconvolution procedure is difficult to be conducted due to the higher thermal emission of the samples.

The measurements carried out for the fading of the peaks showed that the peak 1 has a fading of approximately 9 hours and the peak 2 has longer fading – about 12 hours. The latter and the fact that the enhancement of the sensitivity is in an order orders of magnitude higher shows on the possibility to use the ZrO_2 doped with Er_2O_3 and co-doped with 8 to 10% of Li_2CO_3 as a potential phosphor for short term UV measurements.

Acknowledgements

One of the authors (N. Uzunov) would like to acknowledge the support received from the ICTP, Trieste, Italy and in particular the Program for Training and research in Italian Laboratories. A great part of this work has been sponsored by Grant RD – 05-221/04.03.09 from the Shumen University "K. Preslavsky", Bulgaria.

References

[1] Y. Hatayama, S. Fukumoto, S. Ibuki, Jpn. J. Appl. Phys. **31**, 3383 (1992).
[2] M. Prokic, Appl. Rad. and Isotopes, **52**, 97 (2000),
[3] W. C. Hsieh, C. S. Su, Journal of Physics D: Applied Physics, **27,** 1763 (1994).
[4] N. M. Uzunov, H. Y. Hristov, N. N. Arhangelova, I. P. Penev, V. Marinova, M. Bello, G. Moschini, Assessment of trap parameters related with thermoluminescence peaks in BGO single crystals doped with ruthenium and vanadium, to be published in Journal of Luminescence.

*Corresponding author: Nikolay.Uzunov@lnl.infn.it