OPTOELECTRONICS AND ADVANCED MATERIALS – RAPID COMMUNICATIONS Vol. 3, No. 8, August 2009, p. 845 - 847

Thermoluminescence dosimetric features of clear crystal glass

S. JIPA[a,b], T. ZAHARESCU[a*], R. SETNESCU[a,b], I. V. POPESCU[b], C. OROS[b]
[a]*INCDIE ICPE CA, 313 Splaiul Unirii P. O. Box 149, Bucharest 030138, Romania*
[b]*"Valachia" University of Targoviste, 18-22 Unirii Av., Targoviste 130082, Romania*

The thermoluminescence emission of clear crystal glass for dosimetric application on the low dose range (0.01-10 kGy) was investigated. The glass composition of studied glass was found to be a good option for the foreseen purpose. The TL maximum placed at 187^{0}C was not shifted towards other temperatures after □-irradiation. The linear response was found over the large dose domain (5 Gy – 50 kGy), which is a suitable feature for dosimetric measurements. The fading characteristics of crystal glass are good by its storage at -9^{0}C. Under this condition the decrease in the peak intensity is about 15 % at 30 h of storage. The incessant maintaining at low temperatures the relative response intensity of this dosimetric materials leads to a constant value of about 68 % after more than 150 h from the end of exposure.

(Received June 22, 2009; accepted July 20, 2009)

Keywords: Crystal glass, γ-irradiation, Thermo luminescence, Low dose

1. Introduction

Thermoluminescence (TL) is a sensitive thermal analysis procedure with which the structural changes can be developed for the characterization of radiation effects in solids after the thermally stimulated emission following the recombination between induced defects.

The enlarging applications of gamma radiation in economical areas and human health require available simple and practical methods for radiation dosimetry. Although many substances belonging to various classes of organic, as well as inorganic compounds are used as dosimetric systems, the calling for the development even more systems has still not lost urgency.

Thermoluminescence has been extensively applied in radiation dosimetry [1], archeological dating [2], geology [3] and academic studies [4, 5]. Thermoluminescence glow curve analysis is also a suitable procedure applied in the characterization of the effects of impurities, natural and induced imperfections, color centers and trap distributions. Thermoluminescence of common glass has been already investigated by several authors [6 – 14]. The aims of these studies include the possibility of employing these materials for dosimetric purposes. Much research efforts were spent for the correct characterization and understanding of dosimetric features of large categories of compounds and for the development of new thermoluminescence dosimetric materials [15, 16] with applications on different dose ranges. Under this abundance of information a unified model for the explanation of TL phenomena was reported [17]. The complexity of TLD functionality arises from the conversion ways from incidental radiation to TL photons.

Although many investigations of the TL properties of glass phosphors have been performed, the kinetic parameters and some of the dosimetric characteristics such as dose response and fading behaviors of glow peaks are not studied in detail yet for very low dose exposure. The goal of this work is the analysis of the thermoluminescence dosimetric features of the clear crystal glass and the recommendation of their use in accidental dosimetry on the dose range covering 0.01 to 10 kGy domain.

2. Experimental

The chemical composition of the investigate crystal glass samples was 62.61 % SiO_2, 18.22 % PbO, 15.20 % K_2O, 1.89 % Na_2O, 0.25 % CaO, 0.11 % MgO and about 1.72 % other components. The glass samples were grinded up to ~ 0.15 mm grain diameter.

Gamma irradiation of crystal glass samples encapsulated in plastic ampoules was performed at room temperature by their exposure in GAMMATOR M-38-2 irradiator provided with ^{137}Cs source at a dose rate of 0.4 kGy.h^{-1}.

The thermoluminescence (TL) measurements were preformed with LTM Fimel apparatus on the glass samples of 4 mg. The thermoluminescence glow curves of studied samples were obtained on a large temperature range between room temperature and 450^{0}C. The linear heating rate was set up at 5^0/s and all measurements were taken at ambient atmosphere. The TL investigations were carried out soon after the end of each exposure except the measurements for fading characterization.

3. Results and discussion

The thermoluminescence can be observed in many materials. However, a few materials show the properties required for dosimetry. Thus, a thermoluminescent material is a system that during its exposure to ionizing radiation absorbs energy which is stored.

The dosimetric applications are strictly related to the number and of defects and energy distribution of emitted photons by TL system. The position of prominent thermoluminescence glow-peaks determines the selection for dosimetric evaluation, because it represents an illustration of the energetic requirement for recombination process. The dosimetric peak has to present convenient intensity and temperature as far as possible from room value. Fig. 1 shows the thermoluminescence glow curves recorded for clear crystal glass samples irradiated at different dose levels. It may be seen a broad TL peak located at 187^0C. The position of this peak remains almost at the same temperature irrespective of irradiation dose.

The dose response of TL intensity to γ-irradiation (exposure to ^{137}Cs source) is shown in Fig. 2. The samples have responded linearly on the range between 5 Gy and 5.10^4 Gy that demonstrates the availability of crystal glass for easy evaluation of received doses. It should be noticed that on this dose domain there is not indication concerning response saturation. The TL response presented by this material displays a suitable behavior for personnel accidental dosimetry.

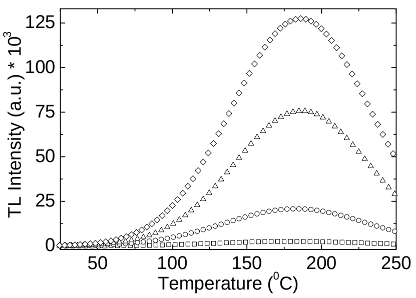

Fig. 1. Thermoluminescent glow curves of clear crystal glass samples after irradiation at different gamma doses. (□) 0.5 kGy; (○) 2.9 kGy; (Δ) 12.5 kGy; (◊) 40 kGy.

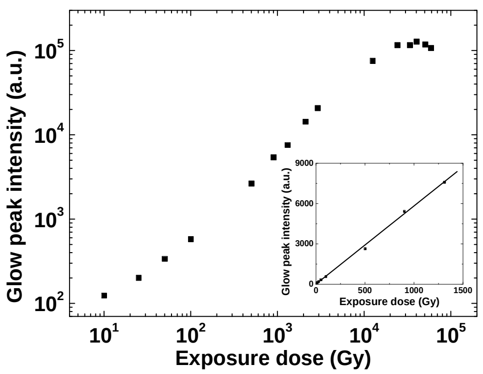

Fig. 2. Dose dependence of the TL response of clear crystal glass.

The room temperature stability of stored thermoluminescent signal following irradiation is dependent on the storage temperature and it must be assessed for the evaluation of information storage along unfavorable conditions of handling. This effect called fading was studied by daily performing measurements up to 165 h (Fig. 3). This figure shows that the glass has initially a fast fading rate and after about 24 hours the fading rate was dramatically reduced remaining at a constant value.

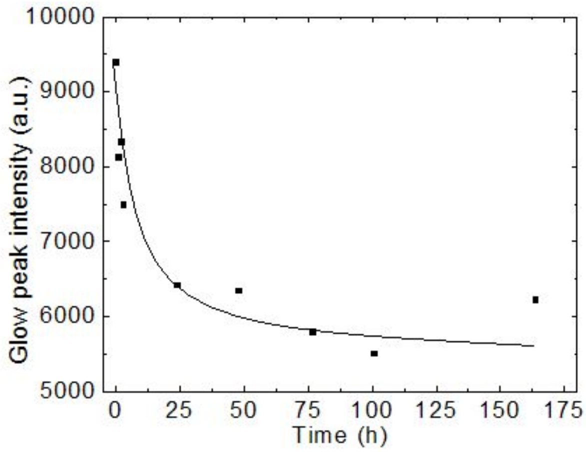

Fig. 3. Thermal fading of glass samples stored at room temperature.

The Fig. 4 shows the thermal fading of crystal glass samples stored at low temperature. These samples received 1.3 kGy by gamma irradiation and then they were maintained in a freezer (-9^0C) immediately after the end of exposure. TL measurements were performed on a period of 15 days. After the first 24 h an approximate 10 % reduction in the thermoluminescence response was observed. It is recommended that the exposed dosimeter may be stored or handled in an opaque container, carton or envelope for further stage of operation.

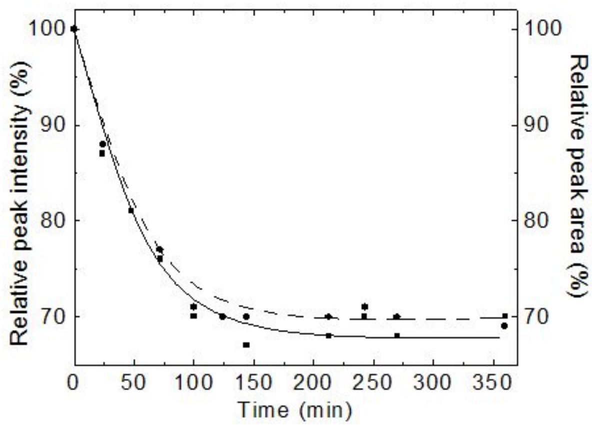

Fig. 4. Thermal fading of glass samples stored at low temperature (- 9^0C). (■) upper curve: area data; (●) lower curve: intensity data

The exposure of crystal glass samples on the action of room light shows an emphasized fading effect that is presented in Fig. 5. The prominent diminution occurred in the value of TL intensity measured to room light imposes the quick handling of samples accompanied by low temperature storage. The decrease observed in the emitted TL intensity suggests that the centers are predisposed to photoluminescence induced by visible light.

For the reproducibility study on crystal glass TLD a couple of clear crystal glass samples subjected five times to the same procedure of γ-irradiation (1.3 kGy) in order to study the response reproducibility after several operational cycles of exposure/ measurement /annealing showed that maximum standard deviation for TL intensity was 5.2 %.

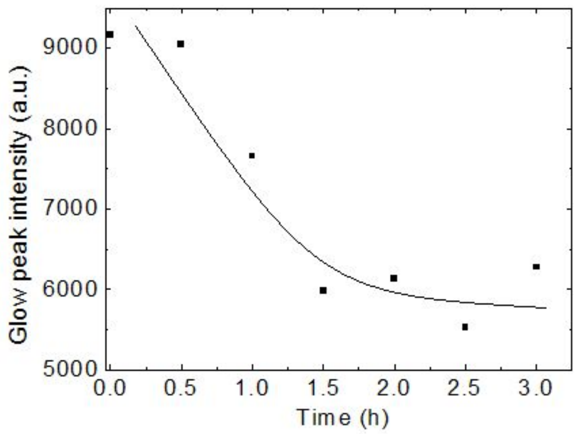

Fig. 5. TL fading under room light exposure.

4. Conclusions

Our results show the importance of a convenient dosimeter which presents simple shape of glow curve. The TL glow peak lies at 187^{0}C, a convenient temperature for considering it as dosimetric maximum. Clear crystal glass shows TL properties on the low dose range, up to 50 kGy. The measurement of gamma doses highlighted the linearity, the good fading response and the reproducibility of this kind of solid dosimeter, which is very cheap, easy to be obtained, non sensitive to humidity, chemically inert relative to several environments and stable over. This material has suitable dosimetric response for the exposure evaluation during several activities in nuclear areas, accidental events, and many other processes managed inside this dose range.

References

[1] C. Furetta, P. S. Weng, Operational Thermoluminescence Dosimetry, World Scientific Pub. Co. Inc., Singapore, New Jersey, 1998

[2] M. J. Aitken, Thermoluminescence Dating, Academic Press, London, 1985

[3] S. W. S. McKeever, Thermoluminescence of solids, Cambridge University Press, UK, 1988

[4] S. Jipa, T. Zaharescu, R. Setnescu, W. Kappel, J. Optoelectron. Adv. Mater. **9**, 1623-1625 (2007).

[5] S. Jipa, T. Zaharescu, W. Kappel, M. Secu, C. E. Secu, M. Lungulescu, A. Mantsch, J. Optoelectron. Adv. Mater. **10**, 554 (2008)

[6] S. M. Brekhovskikh, B. E. Romanov, Z. Priklad, Spektroskop. **5**, 539 (1966)

[7] R. Bernath, J. Mater. Sci. Lett. **14**,1728 (1995)

[8] T. Hashimoto, M, Takano, Y, Yanagawa, T. Tsuboi, J. Environ. Radioact. **50**, 97 (2000)

[9] L. V. E Caldas, M. I. Teixeira, Radiat. Protect. Dosim. **101**, 149 (2002)

[10] F. A. Balogun, F. O. Ogundare, M. K. Fasasi, Nucl. Instrum. and Meth. **A505**, 407 (2004)

[11] L. V. E. Caldas, M. I. Teixeira, Radiat. Protect. Dosim. **111**, 13 (2004)

[12] M. I. Teixeira, Z. M. DaCosta, C. R. DaCosta, W. M. Pontuschka, L. V. E. Caldas, Radiat. Measur. **43**, 480 (2008).

[13] P. Narayan, S. G. Vaijapurkar, K. R. Senwar, D. Kumar, P. K. Bhatnagar, Radiat. Protect. Dosim. **130**, 319 (2008)

[14] P. Narayan, K. R. Senwar, S. G. Vaijapurkar, D. Kumar, P. K. Bhatnagar, Appl. Radiat. Isotop. **66**, 86 (2008)

[15] S. W. S. McKeever, M. Moscovitch, P. D. Townsend (ed) Thermoluminescence dosimetry materials: properties and uses, Nuclear Technology Publishing, Kent, UK (1995)

[16] D. R. Vij (ed) Thermoluminescent materials, PTR Prentice-Hall, New Jersey, USA (1993)

[17] Y. S. Horowitz, Nucl. Instrum. and Meth. **B184**, 68 (2001).

*Corresponding author: traian_zaharescu@yahoo.com