

Rare earth Dy activated Li_3PO_4 :Dy phosphors for lyoluminescence dosimetry of ionizing radiations

A.K.Sahu, P.S.Chowdhary, V.Nayar, S.J.Dhoble¹ and K.K.Dubey²

Department of Physics, C.M.D.P.G. College Bilaspur, Chattisgarh 495001, India.

¹Department of Physics, RTM Nagpur University, Nagpur-440033, India.

²Gramya Bharti Vidyapith Hardibazar Korba, Chhattisgarh, India.

Abstract

Rare earth Dy doped Li_3PO_4 phosphate based phosphors were prepared by high temperature solid state diffusion technique. The peak LL intensity initially increases with increasing mass of the sample, then tends to attain a saturation value for higher mass of the solute added to the solvent. Earlier experiments on gamma irradiated crystals have proved that the light emission originates from the recombination of released F-centres with trapped holes (V_2 -centres) at the liquid-solid interface. In this paper lyoluminescence (LL) characteristics of Li_3PO_4 :Dy phosphors have been reported. These LL characteristics of Li_3PO_4 phosphor may be useful for high radiation dosimetry using LL technique.

Keywords: Li_3PO_4 , lyoluminescence, ionizing radiations

INTRODUCTION

Lyoluminescence (LL) is the phenomenon of light emission when certain substances irradiated with ionizing radiation, are dissolved in a suitable solvent and has been investigated by number of researchers for use in dosimetry application [1-3]. The exciton theory appears attractive because it is easy to imagine trapped energy being directly transferred to water. Arnika et al [4] published their observations proposing the formation of hydrated electron as pre-requisite for the light emission process. Alkali halides are known to develop color centers upon exposure to γ -rays. Several organic and inorganic materials possess the LL property and the most widely studied LL material has been alkali halide [5] and amino-acid [6]. With inorganic materials such as alkali halide, the reaction of trapped electrons from F centres is responsible for the light emission.

In recent years, several sulphate based phosphors [7-8], that possess properties useful for thermoluminescence dosimetry of ionizing radiations, have been reported. Dhoble [9] reported the preparation of (K:Eu)NaSO₄ phosphor for lyoluminescence dosimetry of ionizing radiation. Temperature effect on lyoluminescence of potassium halide microcrystals in luminol solution was reported by Chandok et al [10]. Effect of lyoluminescence decay in impurity doped KCl microcrystalline powder in lyoluminescence dosimetry of ionization radiation is reported by Sahu et al [11]. Nayar et al [12] studied the mass and temperature dependence of lyoluminescence intensity of microcrystalline powder of KCl.

In order to investigate new materials for LL dosimetry of ionizing radiation, we have chosen phosphate based phosphors. In the present paper, LL results in Li_3PO_4 :Dy have been studied.

Here we concentrate on the preparation of Dy activated Li_3PO_4 phosphors by the modified solid state method. The synthesis, LL characterization of Dy activated Li_3PO_4 phosphors have been reported in this paper.

EXPERIMENTAL

The phosphor was prepared by solid state diffusion method.

The starting materials used were of analytical grade. Samples of Li_3PO_4 doped with different rare earth were prepared according to the modified solid state method. High purity starting materials Li_2CO_3 (Merck, 99.9%), $\text{NH}_4\text{H}_2\text{PO}_4$ (Fisher), Dy_2O_3 (Sd fine, 99.9%), were used in synthesis. The reaction was carried out in two steps. In first step all the starting materials were taken in a proper stoichiometric ratio. There are grounded thoroughly with the help of agate mortar pestle for 1h, after crushing, the samples were kept in furnace which is preheated at 300°C, for 3hrs. In second step, when the heat treatment of 3h is completed the materials were again crushed for 1h and kept in furnace for final firing at 500°C for 24hrs. The dried samples were then used for further study. Formation of the compound was confirmed by X-ray diffraction (XRD) pattern.

The LL reader fabricated for lyoluminescence measurements consists of a lyoluminescence cell, a high detector signal processor and a storage oscilloscope. The lyoluminescence cell and the PMT were kept in a light tight box. The solvent is injected by a conventional hypodermic syringe. The light emitted during the dissolution was detected by RCA -931 photomultiplier tube. High voltage power supply was used to bias various dynodes of PMT. PMT output was amplified by a d.c. amplifier. The amplified output was fed to a storage oscilloscope. All experimental procedure was conducted in a dark room at room temperature. For recording LL spectra filters were placed between LL cell and photomultiplier tube. The experiment was repeated several times in identical experimental conditions to ensure reproducibility.

RESULTS

Fig 1. shows the time dependence of ML intensity of Li_3PO_4 :Dy sample for different concentrations of Eu ion. It is seen from the figure that when γ -ray irradiated microcrystals are dissolved in fixed volume of H_2SO_4 (3ml), initially the LL intensity increases with time, attains a maximum value at a particular time, then it decreases and finally disappears.

Figure 2. shows the dependence of peak LL intensity I_m on the

quantity of solute dropped into the solution. Curves in the figure show that the peak LL intensity initially increases with increasing mass of the sample, then tends to attain a saturation value for higher mass of the solute added to the solvent.

Figure 3. shows the dependence of t_m on the quantity of solute dropped in to the solution for microcrystalline powder of $\text{Li}_3\text{PO}_4:\text{Dy}$. It is observed from the curves that the time t_m increases with the increase in the quantity of the solute dropped into the solvent for some phosphate based phosphor.

Figure 4. shows the variation in peak LL intensity I_m of γ -irradiated microcrystalline powder of $\text{Li}_3\text{PO}_4:\text{Dy}$ with the volume of the solvent. For $\text{Li}_3\text{PO}_4:\text{Dy}$, it is found that peak LL intensity increases with increasing volume of the solvent and attains an optimum value for a particular volume i.e. 3 ml and then further decreases with further increase in the volume of the solvent.

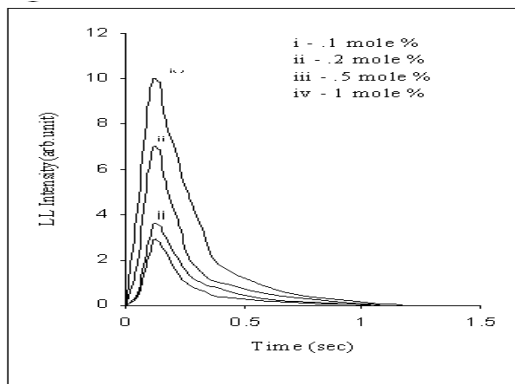


Fig 1 LL Glow curves of $\text{Li}_3\text{PO}_4:\text{Dy}$ powder with H_2SO_4 as solvent for different concentration of Dy.

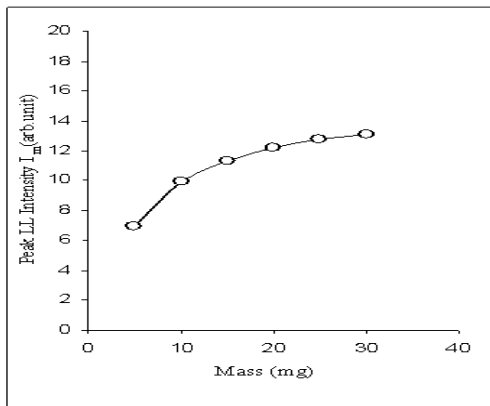


Fig. 2. Variation in peak LL intensity I_m with mass of $\text{Li}_3\text{PO}_4:\text{Dy}$.

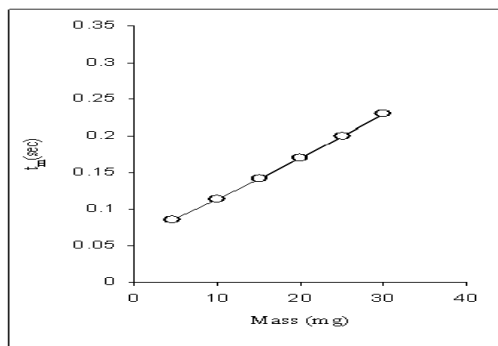


Fig. 3. Variation in t_m with mass of $\text{Li}_3\text{PO}_4:\text{Dy}$.

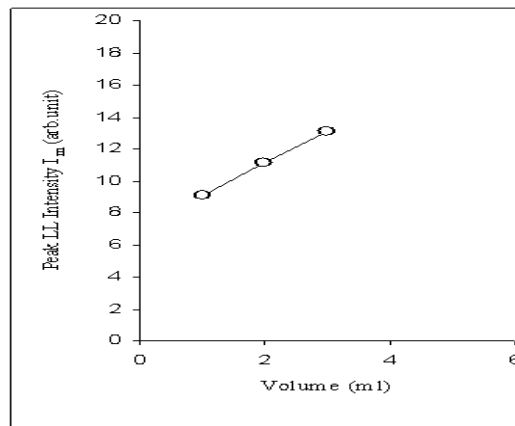


Fig. 4. Variation in Peak LL Intensity I_m of $\text{Li}_3\text{PO}_4:\text{Dy}$ with the volume of solvent.

CONCLUSION

The total LL intensity increases with time, attains a maximum value at a particular time, then it decreases and finally disappears. The peak LL intensity initially increases with increasing mass of the sample. For a higher volume of the solvent in which a particular mass of the solute is dissolved, the average distance between hydrated electron and holes on the surface of solute will increase. It seems that this quenches the occurrence of radiative recombination between the hydrated electrons and holes near the surface of the solute, thereby resulting in a decrease in LL intensity with increasing volume of the solvent. These LL characteristics of Li_3PO_4 phosphor may be useful for high radiation dose using LL technique.

REFERENCES

- [1] K V Ettinger & K Pute, 1982. *J.Int. J. Appl. Radiat Isot.*, 33:1115.
- [2] K V Ettinger & K Pute, 1980. *J. App. I Radiat Isot.*, 33:1115.
- [3] N.A. Atari, 1980. *J.Lumin*, 21:387.
- [4] H. J. Arnika, P. S. Damle, B. D. Chaure, B. S. M. Rao, 1970. *Nature*. 228,357
- [5] N. Yamashita, I. Yammamoto, K. Ninagawa, T. wada, Y. Yamashita & Nakao, 1985. *J. Appl Phys. Part I*, 24, 1174.
- [6] A. Konard, T. Fries, A. Gahh, F. Kummer, U. Herr, R. Tidek & K. Samwer, 1999. *Appl Phys Lett*, 86:3129.
- [7] S. J. Dhoble, S. V. Moharil, S. M. Dhopte, P. L. Muthal & V.K. Kondawar, 1993. *Radiat Eff. Defects Solids*, 127:225.
- [8] S. J. Dhoble, S. V. Moharil, S. M. Dhopte, P. L. Muthal & V.K. Kondawar, 1993. *Phys. Status Solidi(a)*, 135:289.
- [9] S.J. Dhoble, *Rad. Prot. Dos.* 100, 285 (2002).
- [10] R. S. Chandok, R. kaur, G. K. Chandok, B. P. Chandra, 2006. *Ind. J. Pure and App. Phys.* 44, 519.
- [11] V. Sahu, N. Bramhe, D.P. Bisen and R. Sharma, 2009. *J. Opto. & Bio. Mat.* 1, 3, 297.
- [12] V. Nayar, P. S. Chowdhary, P. M. Bhujbal, S. J. Dhoble, 2011. *J. Lum.* 26, 5, 324.
- [13] G. A. Russel. 1955. *J. Am. Chem. Soc.* 79, 3871.