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Effect of UV in $LiMgPO_4$:Tb,B phosphor

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Abstract

Thermoluminescence (TL) and Optically stimulated luminescence (OSL) properties of recently developed $LiMgPO_4$:Tb,B phosphors is studied. $LiMgPO_4$:Tb, is intrinsically sensitive to UV-C photons. There is a linear relation between the OSL output and the logarithm of the spectral irradiance, for exposures ranging from 73.8 to 4428 mJ cm^2. For very small values ranging from 6.15 to 24.6 mJ cm^2, there is a linear relation between the OSL output and the spectral irradiance. Probable mechanism for the intrinsic UV sensitivity is also discussed.

Keywords: *TL, OSL, UV, $LiMgPO_4$:Tb,B*

1.0 Introduction

UV light is widely used in medicine, biology and various industries. It is well known that UV radiation can induce erythema, painful inflammation of the membrane of the eye and skin cancer [1] .Therefore there is an increasing interest in the development of easy and practical methods for ultraviolet (UV) dosimetry. Usually two TL methods, intrinsic and transfer are employed for UV measurement. The latter method requires prior irradiation of the samples to ionizing radiation and subsequent annealing of the samples. This method is time consuming and cumbersome. In the former method, TL phosphors having high intrinsic sensitivity to UV light is used to measure the UV radiation directly. OSL has emerged as a popular dosimetric technique during the past ten years, after the development of crystalline α-Al_2O_3:C phosphor. OSL based dosimeter has various advantages over TL based dosimeter such as faster and multiple readout, absence (no role) of thermal quenching, high sensitivity, possible use of phosphor in plastic (with standing even low temperature) binders etc. In an effort to find alternative OSL phosphor to alumina (α-Al_2O_3:C), several other OSL materials have been synthesized such as KBr:Eu [2], $(NH_4)_2SiF_6$:Tl [3], MgO:Tb [4], $NaMgF_3$:Eu^{2+} [5], $LiAlO_2$:Tb/Ce [6, 7], $ZnAl_2O_4$:Tb [8], $Y_3Al_5O_{12}$:C [9], $MgAl_2O_4$:Tb [10], $LiMgPO_4$:Tb,B (LMP) [11] etc. Among these LMP seems to be the most promising OSL dosimetric phosphor and could be alternative to α-Al_2O_3:C [11]. LMP phosphor has potential to be used in personnel, environmental, medical and high dose dosimetry (Food irradiation) [12]. After the development of OSL technique there is interest in developing OSL phosphors for UV dosimetry. Several efforts are being carried out in this direction. Various materials like (AlN–Y2O3, Al_2O_3:C,KBr:Eu, KCl:Eu, $LiAl(SiO_3)_2$, MgS:Ce, Sm and ZrO_2) have been investigated for their potential to be used as UV dosimeters [12] .UV dosimetry using photo transferred OSL property of Al_2O_3:C has been suggested [13].

In this work we propose to investigate the effect of UV radiation on LMP. The paper also discusses the probable mechanism for the intrinsic UV sensitivity in this phosphor.

1.1 Materials and Methods

For TL measurements, LMP of grain size less than 53 µm was selected. The OSL measurements were carried out in pellets made from LMP phosphor and Teflon ™ as binder. OSL measurements were carried out one day after the exposure using an automatic Riso TL/OSL-DA-15 reader system . A locally made PC based TL readerwith 9125A photomultiplier tube (PMT) having S11 response was used for TL measurements. TL glow curves were recorded one day after the exposure. 5 mg of sample was used to record the TL glow curve each time with the heating rate of 5^{o}C/s unless otherwise specified. The room temperature photoluminescence (PL) spectra were recorded on F-4500 Fluorescence spectrophotometer (Hitachi, Japan) with 150W Xenon lamp, in the wavelength range of 200-800 nm. Slit width for excitation and emission was 2.5 nm each. Pen-ray quartz lamp with major emission at 253 nm was used for UV-C irradiation. The spectral irradiance at the lamp surface was 8mWcm^{-2}, measured using a calibrated radiometer with a 254 nm sensor. UV-B irradiation (380 nm) was carried out using Philips UV lamp. Calibrated ^{60}Co gamma chamber was used for irradiating the phosphor samples to gamma rays.

1.2 Results and discussion

1.2.1 Thermally-stimulated luminescence (TL)

Typical TL glow curve of gamma and UV-C irradiated LMP is as shown in figure 1.It consists of peaks at around 100, 170 and 225 ^{0} C(dosimetric peak). The TL peaks were observed at same temperature in both the cases. This indicates that the traps responsible for TL in gamma irradiated and UV-C irradiated phosphor are same. It was also seen that the sample irradiated with UV–B light showed no TL. The above results show that electrons are generated during UV-C irradiation and these electrons are trapped in the electron traps and recombine at the recombination centre during thermal stimulation giving rise to luminescence.
Phototransferred Thermoluminescence (PTTL) studies were also carried out in LMP. The phosphor was exposed to 10 Gy of gamma dose .The first TL peak at 100 ^{0}C fades away one day after irradiation. This phosphor was then irradiated with UV-B resulting in the regeneration of the first peak at 100 ^{0} C thereby indicating the transfer of charge carriers from deeper traps to the corresponding trap for 100 ^{0} C upon UV-B irradiation. Transfer of charge carriers from deeper traps was also observed after the removal of first two TL peaks and subsequent UV-B irradiation. No PTTL was observed after removing the third peak indicating the absence of deep traps beyond 300^{0} C.

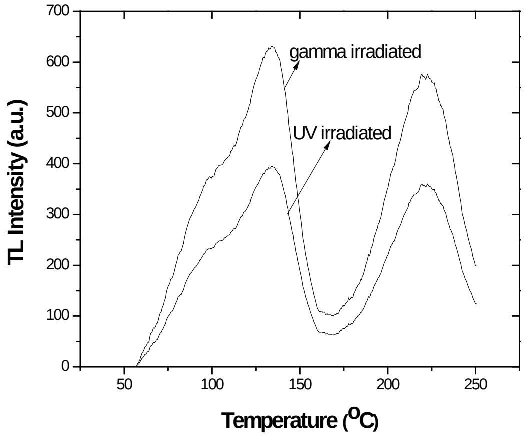

Figure 1. TL glow curve of LMP (a) gamma irradiated ,and (b) UV-C irradiated.

1.2.2 Photoluminescence (PL)

The PL excitation spectrum of LMP (figure 2) consists of a broad band around 240 nm, which corresponds to 4f-5d transitions of Tb^{3+}. The peaks beyond 300 nm correspond to forbidden f-f transitions of Tb^{3+}. The emission spectrum consists of several peaks around 380, 417, 440, 490, 545 and 585 nm corresponding to transitions $^5D_3$ - $^7F_6$, $^5D_3$ - $^7F_5$, $^5D_3$ - $^7F_4$, $^5D_4$ - $^7F_6$, $^5D_4$ - $^7F_5$, and $^5D_4$ - $^7F_4$ respectively.
No appreciable contribution to the 546 nm emission was observed from wavelengths around 380 and 480 nm, which correspond to excitation from $^7F_6$ ground state to $^5D_3$ and $^5D_4$ states respectively. On sustained irradiation of phosphor with 254 nm photons there was no reduction in the Tb^{3+} emission intensity.This shows that there is no reduction in the concentration of Tb^{3+} ion on 254 nm irradiation. This indicates that there is no ionization of Tb $^{3+}$ ion upon UV incidence in the matrix resulting in the formation of electrons. The above result indicate that the induction of TL due to UV is not due to the electron generation from the Tb ion and subsequent trapping of the carriers in the electron traps in the host matrix.

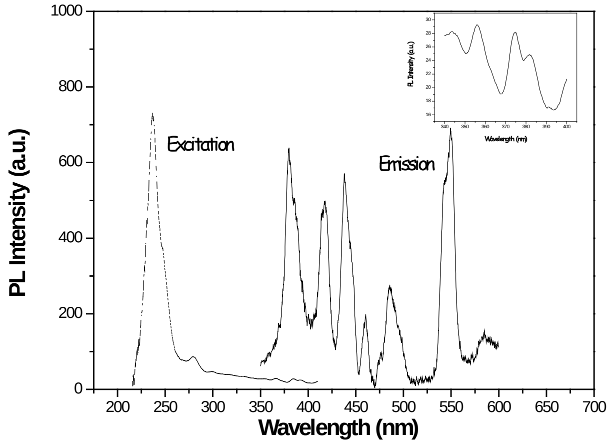

Figure 2. PL excitation (λ_{em}=545 nm) and emission (λ_{ex}=240 nm) spectra of $LiMgPO_4$:Tb,B phosphor. The f-f excitation bands are shown in the inset.

1.2.3 Optically stimulated luminescence (OSL)

In order to study the effect of UV on OSL in LMP, the phosphor was independently irradiated with UV-C and UV-B light.OSL signal was observed from the phosphor irradiated with UV-C photons whereas no OSL was observed from the phosphor irradiated with UV-B photons.

Figure 3 shows the behavior of OSL output versus the UV-C exposure ranging from 6.15 to 8858 mJ cm^{-2}. From the figure it is seen that there is a linear relation between the OSL output and the logarithm of the spectral irradiance, for exposures ranging from 73.8 to 4428 mJ cm^2. For very small values ranging from 6.15 to 24.6 mJ cm^2, there is a linear relation between the OSL output and the spectral irradiance as shown in the inset of figure 3.

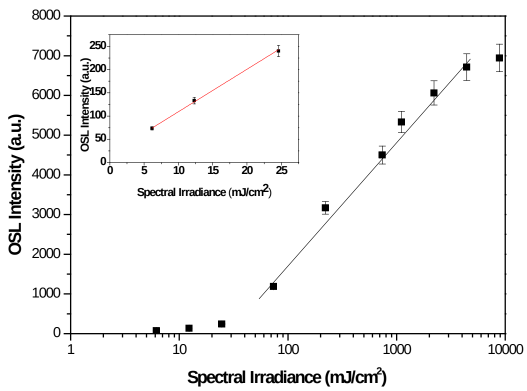

Figure 3. Plot of the logarithm of the TL output of LMP versus UV spectral irradiance ranging from 6.15 to 8858 mJ cm^{-2}.

2.0 Conclusions

$LiMgPO_4$:Tb,B shows high TL and OSL efficiency when irradiated with UV-C photons. The traps responsible for TL in both gamma and UV-C irradiated phosphor is same. The OSL response is linear for spectral irradiance ranging from 6.15 to 24.6 mJ cm^2. From 73.8 to 4428 mJ cm^2 the dependence is linear with the logarithm of the spectral irradiance. Photoluminescence studies suggest that there is no ionization of the rare earth ion during UV-C irradiation. This shows that the UV-C photons generates electron–hole pair in the host matrix and these carriers are trapped in their respective traps and on stimulation the carriers recombine to give the luminescence. The results suggest that $LiMgPO_4$:Tb,B is a good candidate to be explored as UV dosimeter.

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