Thermoluminiscence response of a mixed ternary alkali halide crystals exposed to gamma rays

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Abstract

Ionic crystals, mainly alkali halide crystals have been the subject of intense research for a better understanding of the luminescence properties of defects induced by ionizing radiation. The defects in crystals can be produced in appreciable concentration due to elastic stresses, radiation, and addition of impurities. These defects exhibit remarkable thermoluminescence properties. This work is concerned with the TL properties of a ternary alkali halide crystal after being irradiated with gamma and beta rays. It has been found that the TL glow peak of the crystal follows a rule of average associated to the TL Temperatures of the components of the mixture, similarly to the response of europium doped binary mixed crystals KCl_xKBr_{1-x} and KBr_xRbBr_{1-x}.

Keywords: Materials irradiation, alkali halide crystals, crystalline mixtures, gamma radiation, beta radiation.

1. Introduction

It is well known that thermoluminiscence (TL) is the luminescence observed in thermally stimulated materials [1]. Ancient works report TL studies in insulators giving the effect of ionizing radiation in alkali halides single crystals particularly in europium doped alkali halide crystals [2]. More recently some reports are available about binary crystalline mixtures irradiated with beta rays. [3] A complete characterization of a thermoluminescent material gives a characteristic glow curve related to stability of their traps.

Recently studies with mixed ternary crystals indicate they could be useful for dosimetric applications [4] due to their high temperature TL glow peaks. Principally the high temperature TL response of the ternary crystal $KCl_{0.33}$:$KBr_{0.33}$:$RbBr_{0.33}$:Eu^{2+} after gamma radiation has been studied. [5]

In this work, results of TL in an equimolar ternary alkali halide mixed crystals doped with divalent europium subjected to gamma and beta radiation, knowing thermoluminescence response to heat treatments procedures given to samples prior to irradiation.

2. Materials and Method

The crystals were grown by the Czochralsky method in the facility crystal growing laboratory of the Instituto de Física UNAM, Mexico. KCl, KBr, RbBr and $EuCl_2$ were added to the melt in 0.33 molar fractions. The first irradiation over a ternary sample was with a beta source. For studying the gamma radiation effects of this material, samples were subjected to different thermal treatments. Samples heated at 500°C for 1 hour and then quenched at room temperatures showed strong fractures. Ternary samples were irradiated with a ^{90}Sr/Y source beta radiation 5 sec at a rate of approximately 4.9 Gy·min^{-1}. TL intensity was measured from room temperature to 400°C in a RISO-TL-OSL-15 system. For gamma irradiation samples were subjected to heat treatment at 573, 623 and 673 K for 30 minutes. After that, they were allowed to cool down at room temperature and irradiated in equilibrium with 100mGy of ^{60}Co gamma radiation. The readings were taken two hours after irradiation. In this case, TL analysis of samples was performed with a 4000 Harshaw TL reader, coupled to a PC. TL signal was obtained between 333 and 573 K at a heating rate of $2Ks^{-1}$. All readings were carried out under nitrogen atmosphere, to avoid spurious contributions in the luminescent signal.

3. Results and Discussion.

For beta irradiation, the typical TL emission features are mainly four glow peaks, the first one located at 362, 421^{o}K approximately. The peak emission of TL that occurs around 421°K attracts the attention because it corresponds to more intense peak. The same kind appears in mixtures (X)Cl-(1-X)Br composition and that responds well to halide composition effect on the TL glow peak temperature of mixed crystals [3].

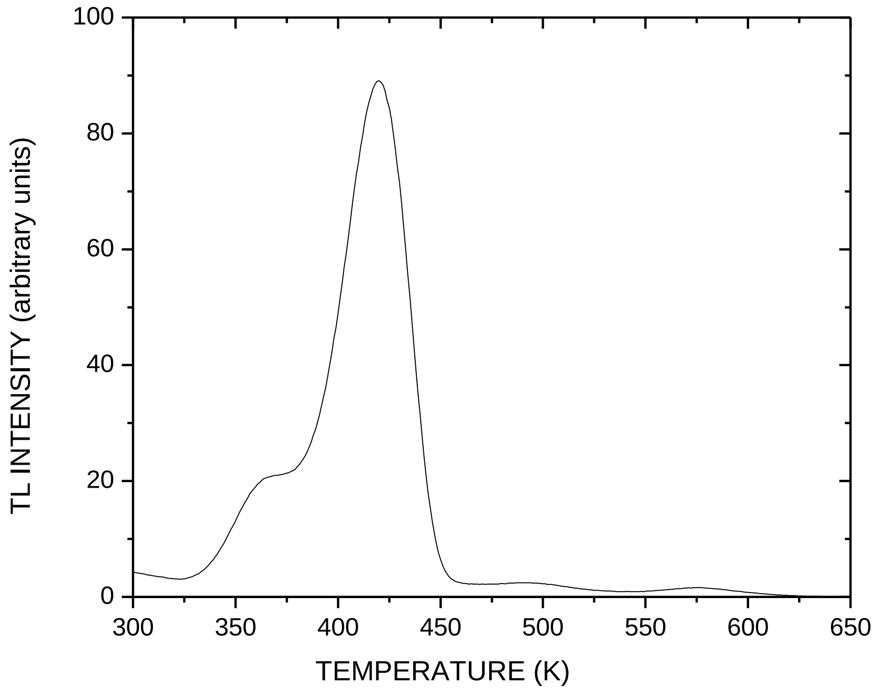

Figure 1.- Glow curve of a ternary crystal thermally treated sample after being exposed to beta ray irradiation.

At temperatures above to 473K there are two glow peaks that can be related to several types of F center aggregates. Low temperature glow peaks of figure 1 are showing that different traps are present in these composite materials.

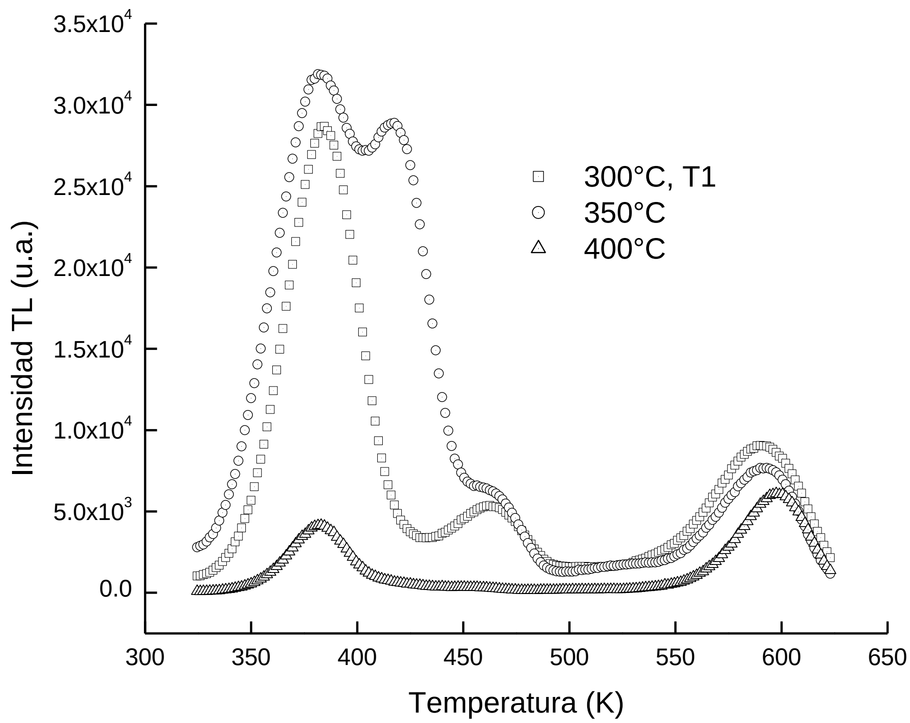

Figure 2.-Glow curves of the samples subjected to different heat treatments

Figure 2 shows the TL glow curves of a sample gamma irradiated after different thermal treatments. Thermal treatment given at 573 K produces a Tl glow curve with three peaks at 384, 462 and 590 K while that given at 623 K, produce a glow curve with four peaks at 381 K, 417 K, 467 K and 590 K. With heat treatment at 673 K, the TL curve showed only two peaks at 583 K and 597 K. This checkup gives the treatment as appropriate at 573 K (300 ^{o} C) to remove the presence of low temperature peaks.

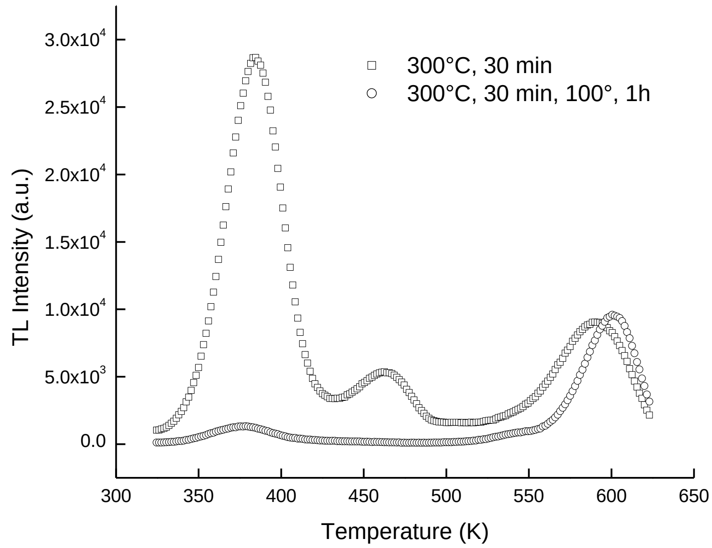

Fig. 3.- TL curves heat treated at 573K (300 ^{o} C), 30 min in the first one and 573 K 30 min then released 1 h at 373 K in the second one.

The same sample was heated to 573 K for one hour prior to irradiation, allowed to cool and irradiate at the same dose. The Figure 3 shows the TL curve obtained with the same parameters of reading. The figure is showing that additional treatment reduces significantly the peak of low temperatures and high temperature peak increases slightly.

4. Conclusions

The procedures followed show that a low temperature glow peak in the beta irradiated sample with the high intense peak at 421 K of Fig 1 is very near to 417 K of figure 2 for the heat treatment at 623 K. The same peaks with different kind of irradiation imply the existence of similar persistent tramps in both materials.

Seeing the ternary crystal as a binary $KBr_{0.5}KCl_{0.5}:Eu^{2+}$ the temperature of the main glow peak obeys the linear dependence of the halogen composition since it is found in the middle between $KBr:Eu^{2+}$ and $KCl:Eu^{2+}$ main glow peaks, while the alkali ions has minor influence in that temperature [3]. It is expected a similar behavior when halogen is Rubidium. The TL of three components mixed crystals with several compositions has to be studied to verify the halogen composition dependence of the glow peak temperature averaging [6].

The possibility of the ternary crystals as dosimetric application can be related to persistent traps near to dislocations, because the mixture has very mechanical tensions and many dislocations.

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REFERENCES

[1] S.W. McKeever *Thermoluminiscence in solids.* Cambridge University Press, (1985).

[2] R. Aceves, R. Perez-Salas, M. Barboza-Flores. *J. Phys. Condensed Matter* **6,** 10397-10405, (1994).

[3] R. Perez-Salas, R. Aceves, R. Rodríguez-Mijangos, H. G. Riveros, C. Duarte. *J. Phys. Condensed Matter* **16,** 491-497, (2004).

[4] R. Rodríguez-Mijangos, R. Perez-Salas, G. Vazquez-Polo. *Optical Materials* **28,** 1398-1400, (2006).

[5] R. Rodríguez-Mijangos, G. Vazquez-Polo, R. Perez-Salas, P. Gonzalez-Martinez, *J. Chem. Chem. Eng.* **6,** 199-208, (2012).

[6] G. Moroyoqui-Estrella, R. Perez-Salas, R. Rodríguez-Mijangos, *Rev. Mex. de Fis.* **57.** 154-157, (2013).