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LUMINESCENCE STUDIES OF RARE EARTH DOPED LITHIUM TETRABORATE

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Rare earth doped lithium tetraborate samples in the glassy state were studied by optical absorption, TL emission and UV excited emission showed the characteristic luminescence of the rare earth ions (4f state). Room temperature luminescence studies showed a high efficiency for the unirradiated samples. The fact also suggests the use of this material for solid state laser development. The dosimetric aspects of $Li_2B_4O_7$: RE were also studied. Having a lower sensitivity than $CaSO_4$ doped with rare earth, $Li_2B_4O_7$: RE showed, however, better general practical characteristics when compared with $CaSO_4$: Dy in the pellet form. The dosimetric properties of polycrystalline pellets of $Li_2B_4O_7$: RE are reported.

1. Introduction

The TL properties of $Li_2B_4O_7$: Mn, Ag have been extensively studied by several authors mainly to apply this material to personnel dosimetry. However, rare earth doped $Li_2B_4O_7$ studies still lack more applied objectives and deeper understanding of its dosimetric properties. It was the purpose of this work to study the luminescent properties of this material and investigate its potential dosimetric applications.

2. Experimental procedures

RE doped $Li_2B_4O_7$ glassy samples were prepared from a powder salt produced by Spex Co. following the procedure proposed by Kirk et al. [1]. RE impurities were added to 0.1–2.0% in weight. SiO_2 powder was added to 0.25% in weight to reduce the hygroscopicity of the final powder samples. This mixture was thermally treated in a graphite crucible at 980°C at room atmosphere when a molten glass was obtained. Subsequently this mixture was cooled down to room temperature when it was obtained as glass sample. These samples were cut in ~1 mm slabs and optically polished for appropriate spectroscopical experiments. For TL experiments these samples were ground to 80/200 mesh grain size powder. Pellets were made by pressing 40 mg of this powder in a 6 mm diameter cylindrical die cell using a pressure of ~2 t. The pellets were finally sintered at 800°C for 30 min to increase their mechanical strength for a routine handling procedure as required for dosimetric purposes. Heat treatments at 360°C for 15 min eliminated all the residual TL after powder/pellet production or for re-utilization of the dosimeter.

3. Results

In fig. 1 the TL emission spectra after a $\sim 10^4$ rad dose from ^{60}Co γ source are shown. These spectra are characteristic of trivalent RE states which confirm the valence reduction mechanism for TL energy storage following the reactions:

$$TR^{3+} + \text{photoelectron} \rightarrow TR^{2+} , \quad (1)$$

$$TR^{2+} + KT \rightarrow (TR^{3+})^* + \text{electron} , \quad (2)$$

$$(TR^{3+})^* \rightarrow TR^{3+} + \text{TL photon} , \quad (3)$$

where the electron in reaction (2) is annihilated by the lattice.

UV induced luminescence studies in glass samples showed stable and efficient RE^{3+} characteristic emission at room temperature without any observable fading. This fact by itself suggests the use of this material for solid state laser applications as in CaF_2 : RE.

In fig. 2 a typical TL glow curve is shown for Tm doped $Li_2B_4O_7$ in the powder and pellet form. For the powder sample a sensitivity was observed 3 times higher than the pellet, which is justifiable by the fact that the optimum sintering temperature used reduces the sensitivity as observed by Nambi [2]. This temperature is well above the "peak cleaning" temperature determined for $Li_2B_4O_7$, which is about 360°C.

In fig. 3 the linearity of the TL response vs. dose is shown starting from a minimum detectable dose of

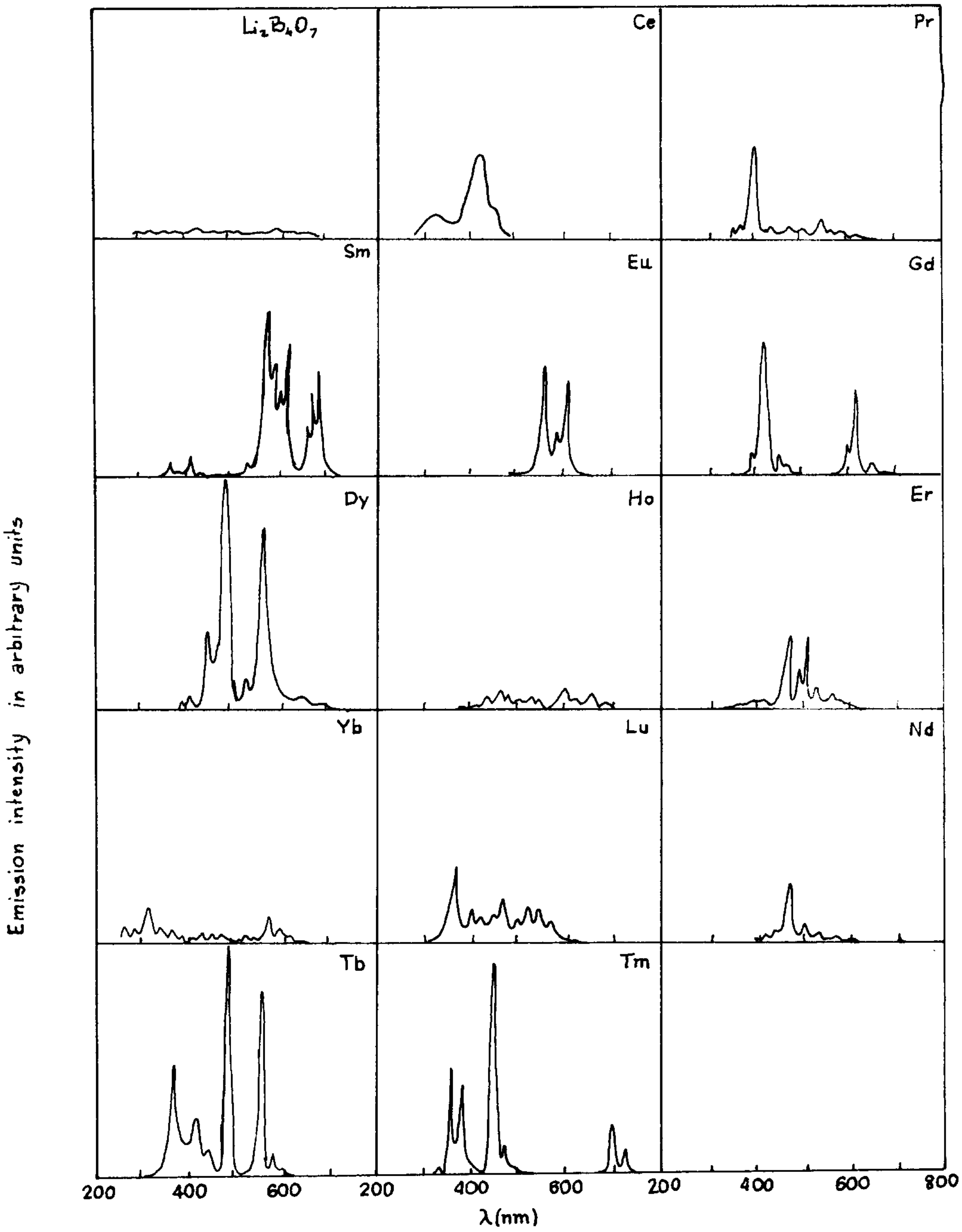

Fig. 1. TL emission spectra of $Li_2B_4O_7$: RE after ^{60}Co 10^4 R.

~10 mRad. In this figure we compare the $Li_2B_4O_7$: Tm that showed the highest relative TL response with $Li_2B_4O_7$: Mn from Harshaw. Our material did not show supralinearity for high doses. Field tests showed good reproducibility and due to a relatively simple method of fabrication and its low cost, $Li_2B_4O_7$: RE seems to have a good future in the applications of TL effects for personnel dosimetry. In fig. 3(b) another advantage of $Li_2B_4O_7$ over other materials is shown which is its low Z. The main disadvantage of this

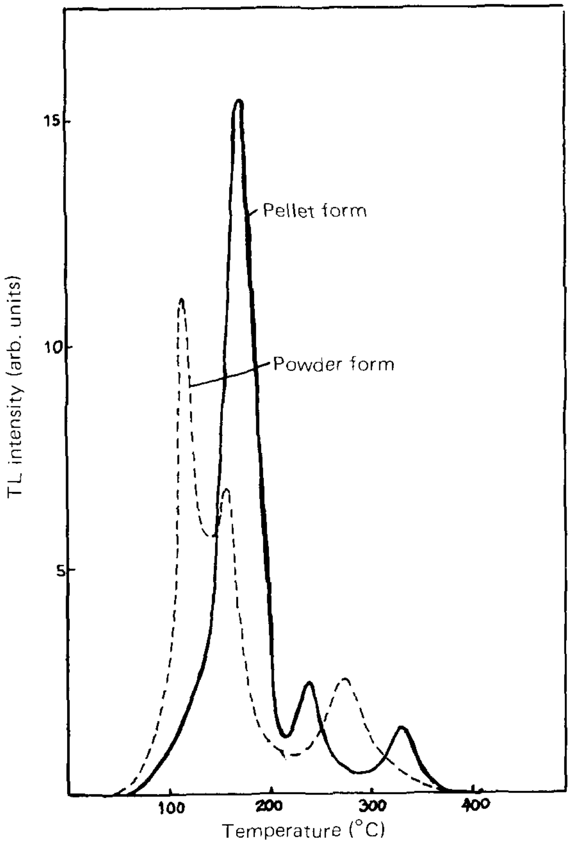

Fig. 2. TL glow curve of $Li_2B_4O_7$: Tm in powder and pellet form.

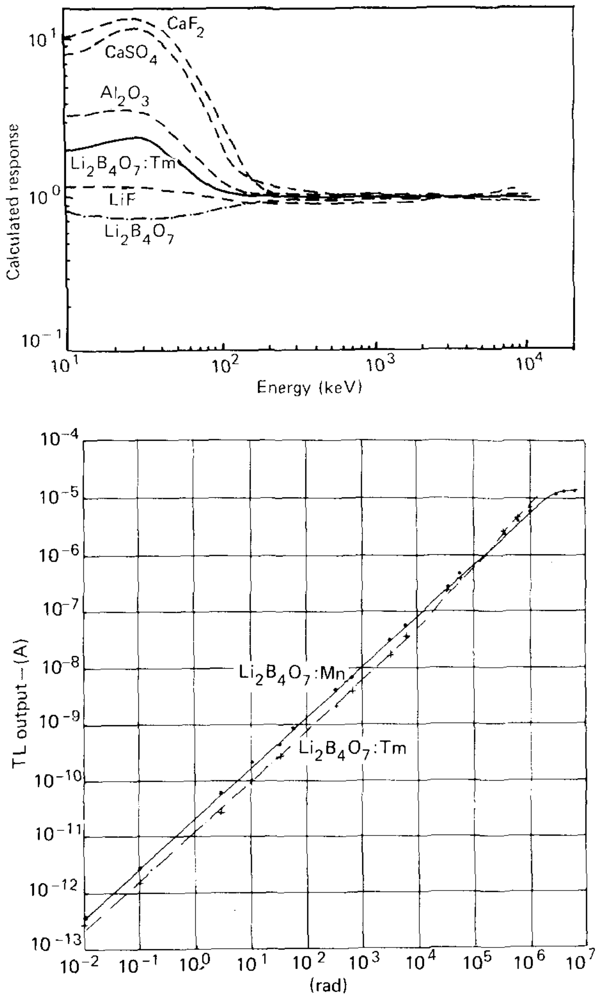

Fig. 3. Linearity of the TL response vs. dose of $Li_2B_4O_7$: Tm compared with $Li_2B_4O_7$: Mn. In the upper part a comparative energy dependence with Z for several materials is shown.

material is its poor sensitivity to low doses. Studies are being made to overcome this difficulty by a combined doping of two or more RE dopants, so as to explore and understand energy transfer mechanisms that would improve energy storage.

References

[1] R.D. Kirk et al., Proc. Symp. org. by IAEA, Vienna, Oct. 1966 (1967).

[2] K.S.V. Nambi, Thermoluminescence: its understanding and applications, IPEN Information No. 54 (1977).