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ABSTRACT

Pellets produced out of thulium doped lithium tetraborate, ($Li_2B_4O_7$:Tm), for thermoluminescent, (TL), dosimetry present low sensibility to environment conditions. Humidity, ambient temperature, fading and handling during TL reading have almost no influence on the TL properties of the pellets prepared according the receipt given in this paper. The structure of the TL glow curve for the irradiated $Li_2B_4O_7$:Tm pellets is rather simple and the TL response is linear in the range of 3×10^{-4} to 7×10^{2}Gy. The dosimetric properties of $Li_2B_4O_7$:Tm in pellet form makes it a competitor with other TL phosphors

PROPRIEDADES DOSIMÉTRICAS DE PASTILHAS DE $Li_2B_4O_7$:Tm

RESUMO

Pastilhas produzidas à partir de tetraborato de lítio impurificado com túlio, ($Li_2B_4O_7$:Tm), para a dosimetria termoluminescente, (TL), apresentam sensibilidade baixa às condições ambientais. Umidade, temperatura ambiente, desvanecimento e manipulação durante a leitura TL não tem influência nas propriedades TL das pastilhas produzidas de acordo com a receita dada neste trabalho. A estrutura da curva de emissão TL das pastilhas irradiadas é razoavelmente simples e a resposta TL é linear no intervalo de doses entre 3×10^{-4} a 7×10^{2}Gy. As propriedades dosimétricas do $Li_2B_4O_7$:Tm na forma de pastilhas torna-o competitivo com os outros detectores TL.

INTRODUCTION

The general requirements for TL phosphors to be used in personnal dosimetry have been well summarized in technical recommendations[1,2,3]. The main requirements are: 1)sensitivity, 2) long term information storage, 3) simple glow peak structure, 4) linear dose dependence, 5) response stability.

Pure $Li_2B_4O_7$ is a TL phosphor that can be easily produced in the laboratory in either polycrystalline or glassy state depending on the cooling rate of the melted mass. This phosphor has been widely investigated for its thermoluminescent behaviour[2,4,6,7,8,9]. In the pure state, $Li_2B_4O_7$ has a nearly energy independent response for low energy photons (20-155 keV region), which makes it an attractive material for TL dosimetry purposes. This work presents a study of pellets made of rare-earth doped $Li_2B_4O_7$. The dosimetric properties of these pellets are reviewed and complement a previous work[6].

EXPERIMENTAL

$Li_2B_4O_7$ was prepared in the laboratory according to the method described by KIRK[4] and 2% (molar) of Tm_2O_3 was introduced as a rare-earth activator. The crystalline mass was ground and sieved to grain sizes smaller than 75 μm, between 75-175 μm and greater than 175 μm. Each two of those groups, of $Li_2B_4O_7$:Tm powder, were mixed in 50-50% proportion to produce 40 mg pellets by pressing the mixture in a 6 mm diameter cylindrical die cell. The best hardness for handling purposes was shown by pellets pressed from 75-175 μm grain sizes only. The pressed pellets however were not rigid enough and required a sinterization made at ~800°C for 30 minutes to increase their mechanical strenght very close to those obtained for LiF (TLD-600) extruded ribbons. The former procedure avoid damage or dissolution of the pellets due to handling or humidity. It was not observed any oxidation effect due to a decomposition of $Li_2B_4O_7$ during the sintering process.

Glow curves were measured in a Harshaw 2000 A-B TL reader. The linear heating rate was set at $7.5°C.s^{-1}$ and the reading cycle was performed within ~50 s with a constant flow of N_2 of $4\ L.min^{-1}$. The pellets were exposed to gamma rays from a ^{60}Co source and to a X-ray generator. Each reported value is an average of five measurements always done 24 h after irradiation.

RESULTS AND DISCUSSIONS

TL glow curve

The TL glow curve, of $Li_2B_4O_7$:Tm pellets, obtained with a test dose of 1 Gy is shown in Figure 1. It is composed by three TL maxima at 181°C, 240°C and 340°C. A considerable dislocation of the peak temperatures (~50°C) to higher values was observed for pellets compared with samples in powder form[7]. This occurs due to the difference of the temperature gradient between the planchet and the upper surface of the pellet or the upper part of the spreaded powder on the planchet (pellet thickness 0.8 mm, powder "thickness" ≈ 0.02 mm).

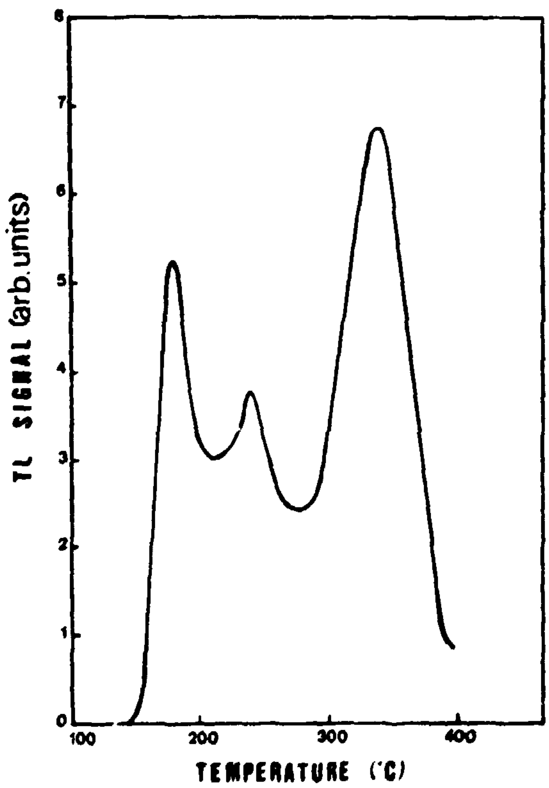

Figure 1 – Thermoluminescent glow curves for Tm activated $Li_2B_4O_7$ in pellet form

Dose versus TL response

The TL output is linear between the minimum detectable dose of $3x10^{-4}$ Gy and $7x10^{2}$ Gy as shown in Figure 2. Above 10^{3} Gy a slight decrease in TL output is observed due to the saturation effect. For special purposes it is possible to reduce the lower limit of dose detection by increasing the surface area of the pellet, keeping the same mass.

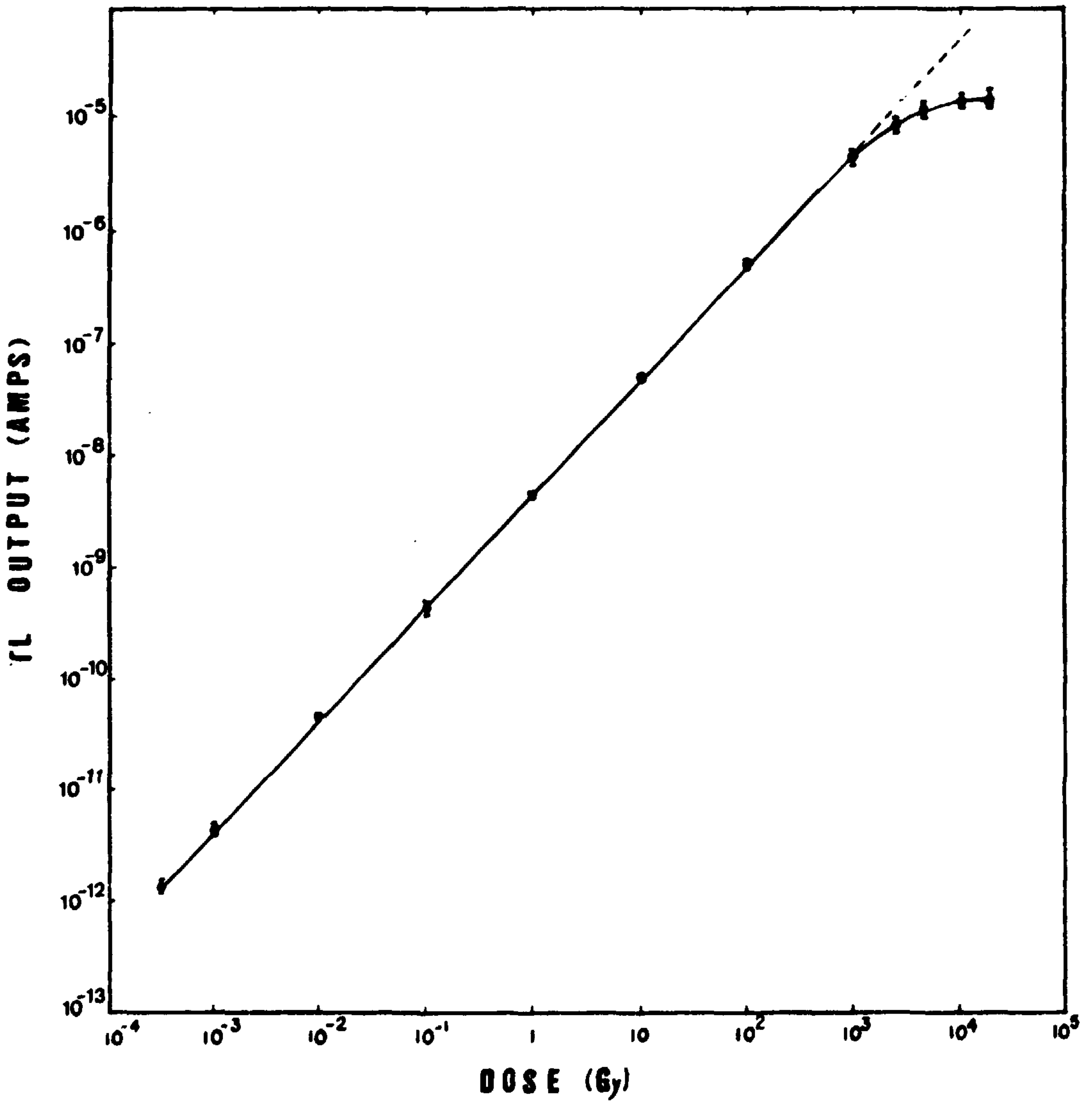

Figure 2 – Thermoluminescent output versus dose for $Li_2B_4O_7$:Tm pellets

Photon energy dependence

As occurs with the $Li_2B_4O_7$:Tm in powder form, the pellets TL response showed also a photon energy dependence.

The X-ray TL response was measured from 20 to 155 keV and normalized for the ^{60}Co gamma radiation (1.25 MeV). The pellets surfaces were always mantained perpendicular to the radiation beam and the irradiation were done in electronic equilibrium conditions. The relative TL output is shown in

Figure 3 for the experimental and calculated values. The errors involved in the determination of the experimental data are about 3.6%.

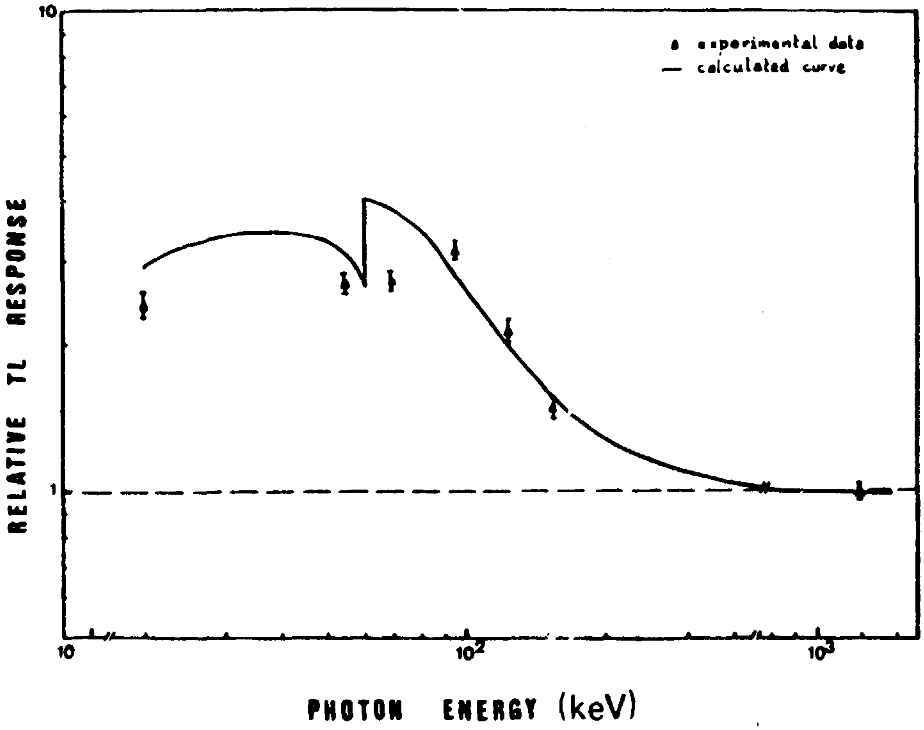

Figure 3 – Relative TL response of $Li_2B_4O_7$:Tm pellets for photon energies in the 20 keV to 1.25 MeV region.

The relative TL response was calculated from the expression proposed by ATTIX[1]:

$$R_{TL} = \frac{[(\mu_{en}/\rho)_{mat} \,/\, (\mu_{en}/\rho)_{air}]_{E_X}}{[(\mu_{en}/\rho)_{mat} \,/\, (\mu_{en}/\rho)_{air}]_{1.25\,MeV}}$$

where $(\mu_{en}/\rho)_{mat}$ stands for the mass energy - absorption coefficient of the TL material, $(\mu_{en}/\rho)_{air}$ corresponds to the same amount for the air and E_X is the X-ray energy. The coefficients (μ_{en}/ρ) of a composed material were obtained from $\sum_i [(\mu_{en}/\rho)_i \, w_i]$, with w_i indicating fractions by weight of the ith-element in the absorber material. Calculated values are very close to the experimental points. The energy dependence in the 70 keV region is mainly due to the Tm impurity in the $Li_2B_4O_7$ matrix.

Reusability

$Li_2B_4O_7$:Tm pellets can be reused at least for 10 times without recalibration in the lower dose interval up to 2.5 mGy. For a test dose of 5 mGy a 50 times reusability was accepted with a maximum observed standard deviation of 6.8%. If, after the heating cycle the pellet remains on the planchet during 5 seconds in 400°C, no further annealing before reutilization is necessary.

For higher doses the standard annealing procedure is recommended before reutilization, to avoid the remaining of any residual TL signal.

Fading characteristics

After a standard annealing procedure and irradiation with 5 mGy of gamma radiation from ^{60}Co, the loss of stored energy was of 1% after one month storage at room temperature (25°C).

For a storage time of three months a 5% fading was observed.

CONCLUSIONS

All the experimental results indicate that $Li_2B_4O_7$:Tm pellets can be used in dosimetry. The energy dependence response can be eliminated by using appropriate filters similarly to those used for $CaSO_4$:Dy + NaCl[5].

$Li_2B_4O_7$:Tm pellets have a competitive behaviour mainly because of its simplicity of production, linear TL response for doses up to 10^3 Gy, comparatively low energy dependence and high reusability conditions if compared with the common commercialized TL phosphors.

REFERENCES

1. ATTIX, F. H. & ROESCH, W. C. *Radiation dosimetry.* New York, Academic Press, 1968. v.1.

2. CHRISTENSEN, P. Manganese-activated lithium-borate crystals, glasses and sintered pellets as thermoluminescence dosimeters. In: AUXIER, J. A., ed.; BECKER, K., ed.; ROBINSON, E. M., ed. *Luminescence dosimetry: proceedings of 2nd International Conference, held in Gatlinburg, Tenn., Sept. 23-26, 1968.* Oak Ridge, USAEC, 1969. p.90. (CONF-680920).

3. COMMISSION OF THE EUROPEAN COMMUNITIES. *Technical recomendations for use of thermoluminescence for dosimetry in individual monitoring for photons and electrons from external sources.* Brussels, 1975. (Radiological protection, 3; EUR-5287).

4. KIRK, R. D.; SCHULMAN, J. H.; WEST, E. J.; NASH, A. E. Studies of TL Li B_4O_7 for dosimetry. In: INTERNATIONAL ATOMIC ENERGY AGENCY. *Solid state and chemical radiation dosimetry in medicine and biology: proceedings of a symposium, held in Vienna, Oct. 3-7, 1966.* Vienna, 1967. p.91.

5. MORATO, S. P.; GORDON, A. M. P. L.; SANTOS, E. N.; GOMES, L.; CAMPOS, L. L.; PRADO, L.; FERREIRA, M. M.; BAPAT, V. N. Development of a solid state dosimetry based on the thermoluminescent properties of $CaSO_4$:Dy crystals. *Nucl. Instrum. Methods,* 200:449, 1982.

6. RZYSKI, B. M. & MORATO, S. P. Luminescence studies of rare-earth doped lithium tetraborate. *Nucl. Instrum. Methods,* 175:62-64, 1980.

7. RZYSKI, B. M. & MORATO, S. P. *The thermoluminescent properties of $Li_2B_4O_7$:Tm.* São Paulo, IPEN–CNEN/SP, 1987. (IPEN-Pub. 114).

8. SCHULMAN, J. H.; KIRK, R. D.; WEST, E. J. Use of lithium borate for thermoluminescence dosimetry. In: ATTIX, F. H., ed. *Luminescence dosimetry: proceedings of International Conference, held in Stanford, Calif., Jun. 21-23, 1965.* Oak Ridge, USAEC, Apr. 1967. p.113. (CONF-650637).

9. TAKENAGA, M.; YAMAMOTO, O.; YAMASHITA, T. Preparation and characteristics of $Li_2B_4O_7$:Cu phosphor. *Nucl. Instrum. Method,* 175(1):77-8, 1980.