

# Dosimetric characteristics and kinetic parameters of LiF:Mg,Ti+PTFE thermoluminescence dosimeters produced in México

J. AZORÍN

*Instituto Nacional de Investigaciones Nucleares  
Salazar, México*

C. BACCI, C. FURETTA

*Università degli Studi di Roma "La Sapienza"  
Roma, Italia*

A. GUTIÉRREZ

*Instituto Nacional de Investigaciones Nucleares  
Salazar, México*

AND

B. RISPOLI

*Università degli Studi di Roma "La Sapienza"  
Roma, Italia*

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**ABSTRACT.** The dosimetric characteristics and the kinetics of the thermoluminescence of locally made LiF:Mg,Ti+PTFE pellets irradiated with  $^{60}\text{Co}$  gamma radiation were investigated. A typical seven peaks glow curve was obtained. The dosimetric peak (peak V) appeared at 503 K, with a sensitivity of 1.5 relative to TLD-100 and fading of 1.8% over one month at room temperature. The trapping parameters, namely, the order of the kinetics, the activation energy and the frequency factor were also investigated.

**RESUMEN.** Se investigaron las características y la cinética de dosímetros termoluminiscentes de LiF:Mg,Ti+PTFE elaborados localmente. Se obtuvo una curva termoluminiscente (curva de brillo) típica de siete picos. El pico dosimétrico (pico V) apareció a 503 K, mostró una sensibilidad de 1.5 con relación al TLD-100 y un desvanecimiento de 1.8% en un mes a temperatura ambiente. También se investigaron los parámetros cinéticos, orden de la cinética, energía de activación y factor de frecuencia.

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## 1. INTRODUCTION

The Harshaw patent to produce lithium fluoride doped with magnesium and titanium (LiF:Mg,Ti) thermoluminescent dosimeters (TLD) has expired and therefore the interest

in producing additional preparation of this phosphor has increased. At the Instituto Nacional de Investigaciones Nucleares (ININ) of Mexico, the research group on TL materials and dosimeters has developed a method to prepare LiF:Mg,Ti TL phosphor powder [1,3] and LiF:Mg,Ti bound in polytetrafluoroethylene (LiF:Mg,Ti+PTFE) pellets [2,3] for thermoluminescent dosimetry (TLD).

The dosimetric characteristics of these dosimeters compared with those of TLD-100 under irradiation with  $^{60}\text{Co}$  gamma radiation were investigated. The kinetics involved in the process were studied by applying the deconvolution method to a seven peaks glow curve.

## 2. EXPERIMENTAL PROCEDURE

Materials used in this study consist of LiF:Mg,Ti+PTFE pellets developed at ININ. The preparation of LiF:Mg,Ti phosphor powder is as follows: a few ml of a solution 0.1 M of  $\text{MgCl}_2$  are added to 40 ml of a LiCl solution (0.9 g/ml). Meanwhile, metallic titanium is dissolved in 50 ml of hydrogen fluoride (HF, 48-50%) and then the first mixture is slowly added. Once LiF is precipitated, the sample is centrifuged and washed repeatedly. The precipitate is dried in a Pt crucible and then oven heated in a nitrogen atmosphere at 913 C for 1 hour. The sample is slowly moved to a lower temperature zone to allow crystallization, and then taken out of the oven to be cooled rapidly to room temperature. Finally, the product is crushed and sieved to select powder with grain sizes between 80 and 200  $\mu\text{m}$ .

To obtain LiF:Mg,Ti+PTFE pellets, a mixture 2:1 of the phosphor powder and PTFE resin powder is placed in a stainless steel die to be pressed, at room temperature, at about 1 GPa. Then the pellets are thermally treated over a period longer than five hours in a nitrogen oven at a temperature slightly lower than that of PTFE fusion. The other materials used in this study, for comparison purposes, were TLD-100 ribbons from Harshaw/Fitrol, USA. All the dosimeters used were annealed at  $653 \pm 5$  K for one hour before used.

The radiation sources used were a  $^{60}\text{Co}$  Vickrad 220 unit giving a dose rate of  $235 \text{ Gy}\cdot\text{h}^{-1}$  and a  $^{137}\text{Cs}$  Victoreen 64-764 irradiator at a dose rate of  $2.6 \text{ Gy}\cdot\text{h}^{-1}$ . All the dosimeters were irradiated under electronic equilibrium conditions.

TL readings were made, in nitrogen atmosphere, with a TL system consisting of a Harshaw 2080. The system was connected to an  $x$ - $y$  recorder to obtain the glow curves. A linear heating rate of  $6.1 \text{ K}\cdot\text{s}^{-1}$  from room temperature (approx. 293 K) to 573 K was used in a readout time of 80 seconds.

Each experimental data point represents the mean value of at least five measurements. Dosimetric characteristics studied were: glow curve, sensitivity, linearity, fading and reproducibility of different batches.

Glow curves were obtained directly from the picoprocessor, connected to an  $x$ - $y$  recorder, for virgin and 653 K, 1 h treated LiF:Mg,Ti+PTFE pellets. Relative sensitivity was determined by irradiating simultaneously samples of LiF:Mg,Ti+PTFE pellets and TLD-100 ribbons with  $^{60}\text{Co}$  gamma radiation at an absorbed dose of 100 mGy. Previous to irradiation the samples were submitted to the following annealing treatments: 653 K, 1 h



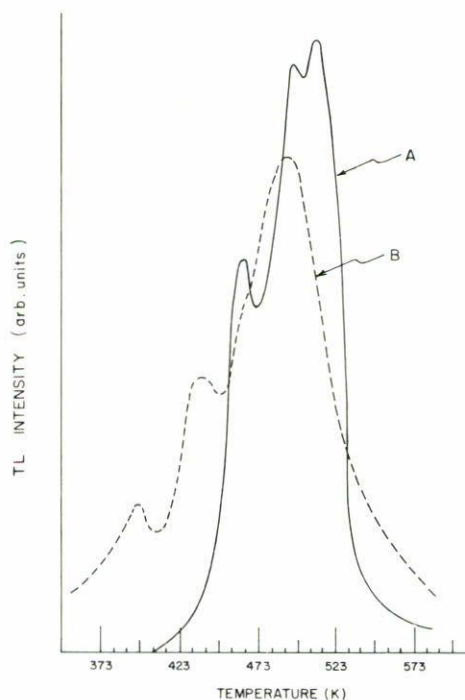


FIGURE 1. TL glow curve of: A) TLD-100 and B) LiF:Mg,Ti+PTFE pellets irradiated with  $^{60}\text{Co}$  gamma radiation at 100 mGy thermally treated at 653 K for one hour.

for LiF:Mg,Ti+PTFE pellets and 673 K, 1 h followed by 2 h at 373 K for TLD-100. The same conditions of readout were used for the two types of dosimeters studied. Linearity of LiF:Mg,Ti+PTFE was determined by irradiating samples of five pellets each at different doses of  $^{60}\text{Co}$  gamma radiation in the range of  $10^{-6}$  to  $10^2$  Gy. Fading of LiF:Mg,Ti+PTFE and TLD-100 was determined simultaneously at three different temperatures (20°C, 37°C and 60°C). The samples, irradiated at 4.5 Gy of  $^{60}\text{Co}$  gamma radiation, were stored, protected from the light, in climatic chambers at these three temperatures. Readings were made over one month. Batch to batch reproducibility was tested by irradiating at the same absorbed dose samples of 10 dosimeters randomly selected from each batch and determining the deviation among the evaluated average doses.

Deconvolution [4] of the glow curve was carried out to isolate the five peaks observed experimentally, fitting the glow curve to a general degree equation by computer. The goodness of the fit was tested by computation of the probability level corresponding to a  $\chi^2$  greater than the experimental value. The parameters determined by this method were: the order of the kinetics, the activation energy and the frequency factor.

### 3. RESULTS

Figure 1 shows the TL glow curve of TLD-100 and thermally treated LiF:Mg,Ti+PTFE pellets irradiated with  $^{60}\text{Co}$  gamma radiation at a dose of 100 mGy. The annealing of the

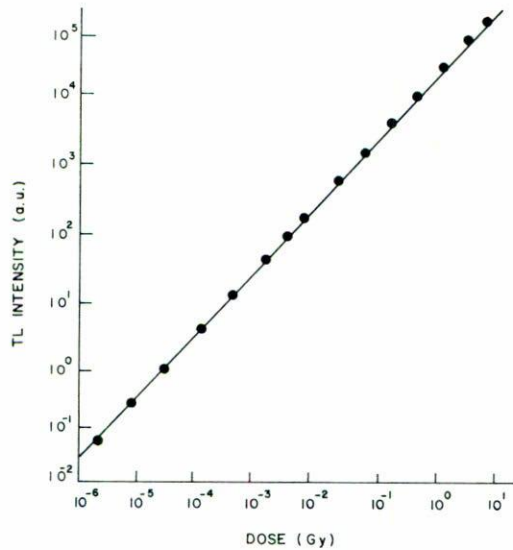


FIGURE 2. TL response as a function of dose of LiF:Mg,Ti+PTFE pellets irradiated with  $^{60}\text{Co}$  gamma radiation.

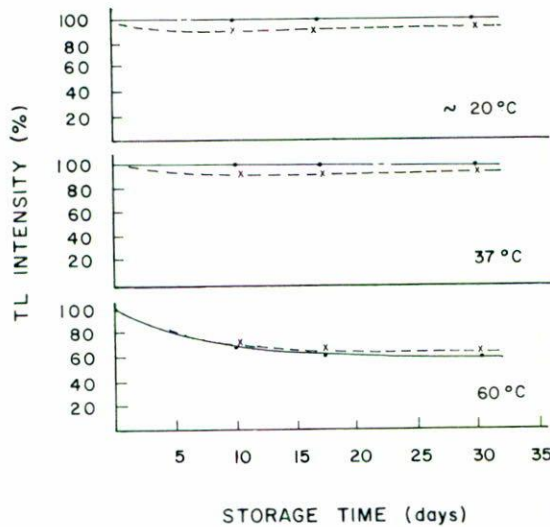


FIGURE 3. Fading, over one month, of LiF:Mg,Ti+PTFE and TLD-100 at three different temperatures: 20, 37 and 60°C (• LiF:Mg,Ti+PTFE; × TLD-100).

pellets at 653 K for one hour modifies its glow curve. This glow curve shows five peaks corresponding to the peaks II, III, IV, V and VI of a typical seven peaks LiF:Mg,Ti glow curve, at 453, 483, 493, 503 and 523 K respectively.

Relative sensitivity of LiF:Mg,Ti+PTFE is shown in Table I. It can be seen that the annealing at 653 K for one hour increase the sensitivity. LiF:Mg,Ti+PTFE showed a linear response from 1  $\mu\text{Gy}$  up to 10 Gy (see Fig. 2) beyond which the supralinear response

TABLE I. Relative sensitivity of LiF:Mg,Ti+PTFE.

Sample	Relative Sensitivity
TLD-100	1
LiF:Mg,Ti+PTFE (virgin)	0.5
LiF:Mg,Ti+PTFE (653 K, 1 h)	1.5

TABLE II. Kinetics parameters of LiF:Mg,Ti+PTFE obtained by means of the deconvolution method.

Peak	Temp. (K)	Kinetic Order	E (eV)	s (s <sup>-1</sup> )
II	453	1.25 ± 0.05	0.878 ± 0.029	(2.3 ± 1.9) × 10 <sup>10</sup>
III	483	1.10 ± 0.08	1.66 ± 0.05	(1.6 ± 1.5) × 10 <sup>15</sup>
IV	493	1.82 ± 0.05	1.80 ± 0.01	(0.78 ± 0.70) × 10 <sup>15</sup>
V	503	1.01 ± 0.02	1.72 ± 0.04	(1.2 ± 1.3) × 10 <sup>16</sup>
VI	523	1.19 ± 0.03	1.70 ± 0.10	(0.19 ± 0.06) × 10 <sup>15</sup>

appears. Fading at room temperature (approx. 293 K) was about 5% in ten days for TLD-100 and negligible for LiF:Mg,Ti+PTFE (ININ). Fig. 3 shows the fading of both dosimeters at three different temperatures over one month. Reproducibility of different batches was better than 5%.

Table II summarizes the results of applying the deconvolution method to obtain the kinetic parameters: kinetics order ( $l$ ), activation energy ( $E$ ) and frequency factor ( $s$ ).

#### 4. CONCLUSIONS

It is now possible to produce locally TL dosimeters of LiF:Mg,Ti+PTFE having similar dosimetric characteristics to that commercially available. The activation energy of peak V determined by means of the deconvolution method is in good agreement with those reported by other authors [5]. It is concluded that LiF:Mg,Ti+PTFE dosimeters locally produced provide the basis for a reliable dosimetry system to be used in medical applications of ionizing radiation. The results of the tests showed that these dosimeters meet the most important requirements for such applications. These dosimeters have been used in radiotherapy and radiodiagnosis for patient monitoring at the main hospitals of Mexico City.

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