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Comparison of the TL responses of two different preparations of LiF:Mg,Cu,P irradiated by photons of various energies

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Abstract

The aim of this work is to present the results concerning the photon irradiation of a new phosphor, the LiF:Mg,Cu,P + PTFE, produced at the Instituto Nacional de Investigaciones Nucleares (ININ—Mexico). The photon irradiations were performed using X-rays of 16, 24, 34.5, 42, 100 and 145 keV, and γ rays from ^{137}Cs (662 keV) and from ^{60}Co (1 252 keV). The results obtained are normalized to the ^{60}Co response. The experimental data are then compared to those obtained using the commercial dosimeters TLD-100 and GR-200A.

Keywords: Photon dosimetry measurements; Dosimetry; Ionization dosimetry; Solid state detectors; Thermoluminescence

1. Introduction

The peaceful use of ionizing radiation, in many fields of science and in many practical applications, needs very accurate measurements of the delivered doses. This is a problem of very high priority in medicine, i.e. in therapy applications and radiodiagnostic examinations. Thermoluminescence (TL) is a method which allows to obtain accurate and precise measurements of the absorbed dose, specially if the thermoluminescent material is almost equivalent to the human tissue (the effective atomic number of tissue, Z_{eff}, is 7.4), i.e. tissue equivalent materials.

In this sense many efforts have been made to produce thermoluminescent materials having properties similar to the human tissue. Lithium fluoride has been the phosphor which is more studied and used in medical applications due to its quasi-equivalence to human tissue ($Z_{eff} = 8.2$) (Cammeron and Suntharalingam, 1968). At first it was doped by Mg and Ti activators and more recently, impurities of Mg, Cu and P were added, to obtain a material having a very high sensitivity, i.e. TL response over dose (Wu et al., 1984; Azorín et al., 1990; González et al., 2005).

In this work three types of lithium fluoride, (i) GR200A (LiF:Mg,Cu,P), (ii) LiF:Mg,Cu,P + PTFE and (iii) TLD-100 (LiF:Mg, Ti) produced in China, in Mexico at ININ and in USA by Harshaw respectively, have been used and their response to different photon energies has been investigated and compared in order to find the best material for medical applications.

2. Experimental method

2.1. Material preparation

The LiF:Mg,Cu,P developed at ININ was prepared following two different preparation methods.

Preparation (A): Twelve grams of LiF superpure powder were put in a platinum crucible and the activators Mg (0.2 M%), Cu (0.05 M%), P (3.0 M%) were added. The crucible was inserted in an oven at a temperature of 1050 °C for crystallization. After that, the material

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obtained was reduced to powder and grains having sizes between 70 and 210 μm were selected. The powder was then mixed with poly(tetrafluoroethylene) (PTFE): 40% of TL material and 60% of PTFE to make pellets (González and Azorín, 2001).

Preparation (B): This preparation was exactly the same of preparation (A) but LiF of analytic grade was used instead of superpure material.

Finally, discs of 5 mm in diameter and 0.6 mm in thickness having an average TL mass of 7.80 ± 0.40 mg were obtained.

The commercial samples GR200A and TLD-100 were discs having 4.5 mm in diameter, 1 mm thickness and an average TL material mass of 27.69 ± 0.91 mg and chips having dimensions $3 \times 3 \times 1$ mm and an average TL material mass of 23.14 ± 0.11 mg.

Before any irradiation, the TL dosimeters were annealed according to the following thermal procedures (Cammeron and Suntharalingam, 1968; Wu et al., 1984; Azorín et al., 1990; González and Azorín, 2001):

- High-temperature annealing:

LiF:Mg,Cu,P + PTFE (preparation A) and GR200A: 240 °C during 10 min,
LiF:Mg,Cu,P + PTFE (preparation B): 280 °C during 10 min,
TLD-100: 400 °C during 1 h.

- Low-temperature annealing.

100 °C during 2 h for all kind of dosimeters.

2.2. Irradiation

For the X-rays irradiations, TLDs of each type were placed in Plexiglas containers having eight holes each. The containers were covered by a sheet of Mylar having a thickness of 0.475 μg/cm^2. The γ irradiations were performed under electronic equilibrium conditions. All the irradiations were performed at Secondary Laboratory of ININ.

The air kerma was measured using an ionization chamber PTW-1152 located at 100 cm from the irradiation source. The irradiation field had a diameter of 8.7 cm. The PTW chamber was calibrated at the *Laboratoire Central des Industries Electriques* (France) and gives the data expressed in electric charge per unit of time (pC/min).

The air kerma for the X-rays was determined locating the PTW chamber in front of the irradiation source. A laser beam was used for getting a very accurate and precise position.

The kerma value, was corrected taking into account temperature and pressure (ICRU Report 23, 1973). The following equation was used for

$$K_1 = \frac{273 + t}{273 + t_0}\frac{p_0}{p}, \quad (1)$$

where t_0 is the specific temperature (20 °C), t is the air ambient temperature, p_0 is the specific pressure (101325 Pa), and p is the air ambient pressure.

The dosimeters were located at the same position of the PTW chamber for irradiation.

Table 1 gives the characteristics of the X-rays used for the TLDs irradiations, and Table 2 lists the kerma values as obtained by the PTW chamber.

Table 1
Quality of X-rays used for the TLD's irradiation

Tube potential (kV)	Photon energy (keV)	Beam quality, HVL (mm)
30	16	0.370 Al
50	24	1.025 Al
80	34.5	2.970 Al
100	42	5.025 Al
200	100	1.690 Cu
250	145	3.200 Cu

2.3. TLD reader

The irradiated TLDs were read out using a TL reader Harshaw 4000. The TL signal was digitalized by a RC 232C interface and integrated from 60 to 240 °C for LiF:Mg, Cu,P + PTFE, preparation A, and GR200A; for LiF:Mg, Cu,P + PTFE, preparation B, the signal was integrated from 60 to 280 °C and for TLD-100 between 60 and 300 °C. A linear heating rate of 2 °C/s was used in all readings. Nitrogen was allowed to flux in the read out chamber to eliminate spurious TL signals. All types of TLDs received a test dose of 0.1 Gy.

3. Results

The readings of the irradiated TLDs were carried out 1 day after the irradiation to allow the decay of low-temperature peaks in the glow curve. During this time the dosimeters were kept under dark conditions at room temperature (RT) (18 °C). After that, the sensitivity of each sample was calculated according to the following equation:

$$s = \frac{\text{TL intensity}}{\text{TL mass} \times \text{dose}}. \quad (2)$$

Table 3 lists the sensitivities for each kind of dosimeters as a function of energy. After that, the individual sensitivities have been normalized to the sensitivity of ^{60}Co and the final results are given in Table 4. These results are plotted in Fig. 1.

The same dosimeters were annealed and then irradiated with X-rays of 24, 42 and 100 keV in the kerma range from 0.05 to 1.00 Gy. As in the previous experiment, the TLDs were read out 1 day after irradiations. Figs. 2–5 show the TL response as a function of the kerma.