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Applicability of pure LiF in dosimetry

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Abstract

The objective of this work was to investigate the thermoluminescent properties of pure LiF in order to estimate the applicability of this material to dosimetry. Irradiations were conducted using photons (gamma and 6 MV X-rays) and megavoltage electron beams (8, 10, 14 MeV). The LiF sample pellets were produced using crystals grown by the Czochralski method. The results obtained in this study can suggest the applicability of pure LiF pellets for dosimetric purposes, provided fading is correctly accounted for. The TL response of the pellets was very intense and with dosimetric peaks in temperatures high enough to overcome most of the fading problems. Although the impurities are very important to TL phenomena, these results showed that a significant portion of the TL response of LiF based materials are due to the radiation induced defects.

Keywords: Pure LiF; Thermoluminescence; Radiotherapy beams

1. Introduction

Thermoluminescence (TL) is one of the techniques most frequently used for *in vivo* dosimetry. Its typical application in radiotherapy is the dose evaluation in critical organs as well as measures in difficult geometries. TL dosemeters (TLDs) have been used in radiotherapy to measure the entrance and exit doses in various tissues, including the skin and lymphatic system. TLDs are small and can be easily adapted to *in vivo* measurements without a significant change in the radiotherapy treatment (Ertl et al., 1997; Duggan and Johnson, 2000).

LiF (with different dopants) is the most common base material used for production of TLD. LiF, in the form LiF:Mg,Ti (MT), has been the mainstay of the TLD industry for many years, and it is the most widely used TLD material on the market since its first introduction, cited by Mandowska et al. (2002).

In the last decade, some papers have been published about the thermoluminescent properties of pure LiF crystal. The aim of those papers was to explain better the relation between the TL signal and the radiation induced defects. Those studies indicate that the TL intensity of the LiF dosemeters is not only caused by impurities but they have also an important contribution of the radiation induced defects (Baldacchini, 2002; Baldacchini et al., 2003, 2007; Davidson et al., 1997, 1999; Flerov and Flerov, 1996).

Although doped TLDs of LiF are efficient dosemeters, it was decided to investigate the thermoluminescent properties of pure LiF in order to estimate its applicability for dosimetry.

2. Experimental

The irradiations were conducted using photons (gamma and 6 MV X-rays) and megavoltage electron beams (8, 10, and 14 MeV). The gamma irradiations ^{60}Co were performed in a Gamma Cell 220 Excel, from MDS Nordion (dose rate = 10.142 kGy/h). The samples were irradiated with doses from 10 to 30 Gy. The irradiations with doses between 0.1 and 2 Gy were performed in a Siemens accelerator of a radiotherapy institution: Hospital Governador João Alves Filho, Aracaju, Brazil. The photon and electron irradiations were obtained by using the composites kept in Lucite badges in order to guarantee electronic equilibrium conditions. Field shaping for electron beams was obtained with electron cones. All irradiations were performed at room temperature.

In order to obtain samples with high purity the pure LiF pellets were produced using crystals grown by the Czochralski

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method. The crystal purity is higher than in the precursor material used (99.99 purity) because impurities segregation occurs during liquid phase. The crystals were grinded, sieved to the size interval of 45–65 μm, pressed and sintered at 750° for 2 h in order to produce pellets of size 6 mm diameter and 1 mm thickness. After the analysis of the reproducibility, 30 pellets were used to the tests. To these pellets a maximum standard deviation of 3.5% was obtained. The TL intensity was monitored while the sample was heated from room temperature to 300 °C at a constant heating rate of 10 °C/s. Two Harshaw TL readers were utilized: a model 5500, for the samples irradiated with ^{60}Co; and a model 3500, for the other irradiations. Before irradiations the pellets were annealed in air at 400 °C for 1 h and rapidly cooling to room temperature.

3. Results

Fig. 1 shows the typical TL glow curve of a pure LiF dosemeter irradiated with 5 Gy (^{60}Co), and evaluated immediately after irradiation. The glow curve exhibits two intense peaks at 150 and 250 °C. This curve presented the same TL peak characteristics for all irradiations. The TL relative efficient of dosimetric peak in our samples was 22% when compared with TLD-100.

Fig. 2 shows the TL response of the LiF samples irradiated between 10 and 30 Gy with gamma radiation. The TL response shows a linear behavior in function of the absorbed dose in this dose range The dosemeters present also linearity in the megavoltage X-ray beam, for a dose range from 0.1 to 2 Gy. The maximum uncertainty of these measurements was 3%, considering the sensitivity was the average TL intensity in five pellets.

The TL response of the dosemeters to electron irradiations depends on the radiation dose, the mean electron energy at the dosemeter position in the phantom, and the size of the dosemeter (Vlado et al., 1996). The TL sensitivity of LiF to different energies of electron beams was also determined by weighting the energy-dependent response. Fig. 3 shows that the TL responses are linear in the dose range from 0.1 to 2 Gy, and that the TL sensitivity are inversely proportional to the electron beam energies.

Post-irradiation fading is a contributing factor that affects the response of a thermoluminescent phosphor as a function of time. The fading phenomenon at room temperature was studied for periods that varied from 1 to 5 weeks. The pellets were previously irradiated to 2.0 Gy (X-Rays, 6 MV), and the samples were stored at room temperature. The TL response faded by about 5% in the first 15 days after irradiation. In the next 20 days, the TL response faded by only 2.5%, tending the TL intensity to a constant value. The fading during the first days of storage can be related to effects of transferring charge from deep traps to the shallow traps that can become emptied at room temperature by isothermal decay. Thus, if the pellets can be used in routine dosimetry, the fading must be taken into account in the determination of absorbed doses.

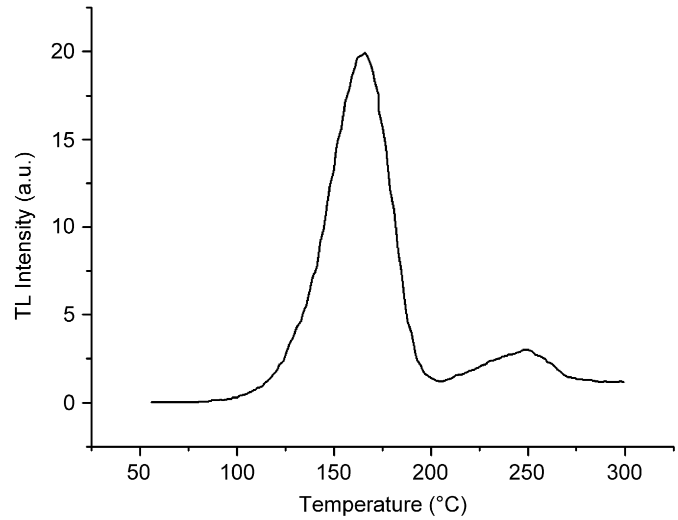

Fig. 1. Typical TL glow curve of a pure LiF detector exposed to electron beams (5 Gy, 10 MeV).

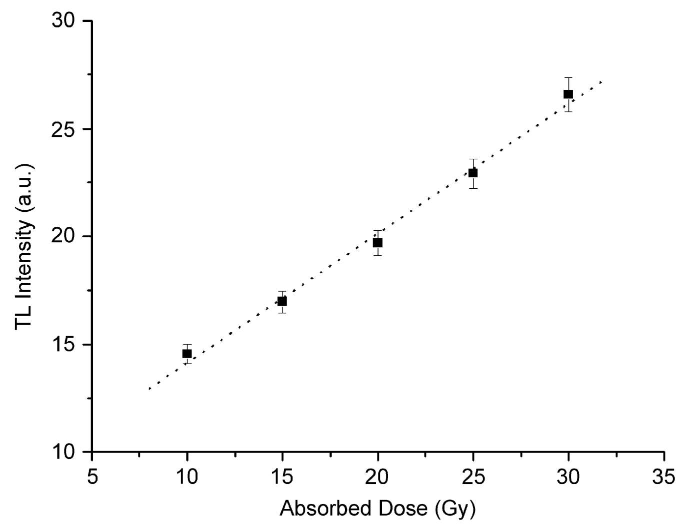

Fig. 2. Pure LiF dose response to gamma radiation.

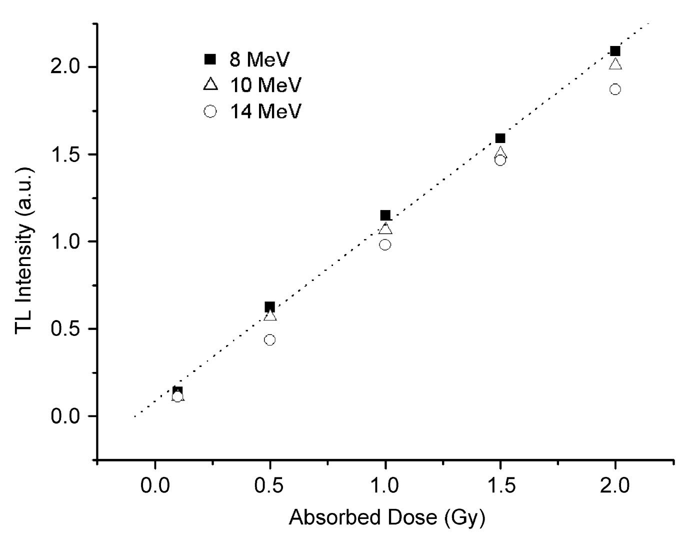

Fig. 3. Pure LiF dose response to electrons beams.

4. Conclusions

The results obtained in this study proved the applicability of pure LiF pellets for dosimetric purposes, especially in radiation therapy beams. The TL response of the pellets is very intense and the TL glow curve shows dosimetric peaks in temperatures high enough to overcome most of fading problems. Although the impurities are very important to TL phenomena, the results obtained in this work suggest that a significant portion of the TL response of LiF based materials is due to the radiation induced defects.

Acknowledgments

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References

Baldacchini, G., 2002. Colored LiF: an optical material for all seasons. J. Lumin. 100 (1–4), 333–343.

Baldacchini, G., Davidson, A.T., Kalinov, V.S., Kozakiewicz, A.G., Marolo, T., Montecchi, M., Montereali, R.M., Nichelatti, E., Voitovich, A.P., 2003. Spectroscopic measurements and thermoluminescence of gamma-ray colored LiF crystals. Opt. Mater. 24 (1–2), 129–135.

Baldacchini, G., Davidson, A.T., Kalinov, V.S., Kozakiewicz, A.G., Montereali, R.M., Nichelatti, E., Voitovich, A.P., 2007.Thermoluminescence of pure LIF crystals and color centers. J. Lumin. 122, 371–373.

Davidson, A.T., Kozakiewicz, A.G., Comins, J.D., 1997. Photoluminescence and the thermal stability of color centers in gamma-irradiated LiF and LiF(Mg). J. Appl. Phys. 82 (8), 3722–3729.

Davidson, A.T., Kozakiewicz, A.G., Wilkinson, D.J., Comins, J.D., 1999. Defect clusters and thermoluminescence in LiF crystals. J. Appl. Phys. 86 (3), 1410–1414.

Duggan, B.M., Johnson, B.L., 2000. Dosimetry of the I-Plant Model 3500 iodine-125 brachytherapy source. Med. Phys. 28 (4), 601–670.

Ertl, A., Zehetmayer, M., Schoggl, A., Kindl, P., Hartl, R., 1997. Dosimetry studies with TLDs for stereotactic radiation techniques for intraocular tumours. Phys. Med. Biol. 42, 2137–2145.

Flerov, V.I., Flerov, A.V., 1996. The role of F centres in the thermoluminescence of lithium fluoride. Radiat. Prot. Dosim. 65 (1–4), 105–108.

Mandowska, E., Bilski, P., Ochab, E., Wiatek, J., Mandowski, A., 2002. TL emission spectra from differently doped LiF: Mg detectors. Radiat. Prot. Dosim. 100, 451–454.

Vlado, R., Zankowski, C., Pla, M.O., Podgorsak, E.B., 1996. Thermoluminescent dosimetry in electron beams: Energy dependence. Med. Phys. 23, 667–673.