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Dosimetric Characterization of LiF Doped with Unusual Dopants

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Abstract. LiF with different dopants has been one of the most investigated materials to use as thermoluminescent dosimeter. Even so, in a previous work we observed that pellets produced with pure LiF have applicability to ionizing radiation dosimetry, showing dosimetric peaks in temperatures high enough to overcome most of fading problems. In this work we studied the thermoluminescent properties of pellets prepared with LiF and unusual dopants. As dopants were tested rare earth metals like europium, terbium, dysprosium and neodymium. The more intense TL response was showed by samples doped with Nd. Although they are bluish due to presence of the Nd, the pellets produced with LiF:Nd exhibited a TL emission two times more intense than the one in pure LiF.

1. Introduction

Of the many types of thermoluminescent detectors (TLD) available, LiF:Mg,Ti (TLD-100) remains one of the most widely used dosimeters in routine personal and environmental monitoring and space dosimetry[1].

TLD is a versatile tool for assessing the dose of ionizing radiation. The variety of ceramic materials and their different physical characteristics allow the determination of quantities of radiation at levels of μGy dose of the kGy, enabling the timing of materials [2-4]. Among the potential termoluminescente dosimeters, materials based on LiF are used in personal dosimetry and deserve attention because of low energy dependence and their equivalence of human tissue [5]. LiF-100H TLD, for example, has a density of 2.6 g/cm^3 with effective atomic number about 8.2**,** close to the 7.4 value of human tissue**.** Lithium fluoride is beyond not soluble in water.

The intrinsic efficiency is defined as the ratio of light energy emitted during heating to energy absorbed during gamma irradiation [6]. LiF presents an intrinsic efficiency of thermoluminescent of approximately 0.04%. This characteristic make it widely used in medical applications. In the LiF:Mg,Ti the excess of positive charge in the grid of lithium fluoride crystal, which implies in the formation of new traps for electrons, is a consequence of the substitution of one lithium ion to other of magnesium. Of all the peaks of issue of LiF: Mg, Ti, about ten, only the so-called peaks 4 and 5 are used in dosimetry, those that occur between the temperatures of 160 and

190°C [11]. The lithium fluoride presents a whole series of dosimetric characteristics that define their applications in specific areas of dosimetry.

In this context, we are searching about the possibilities to produce a new dosimeter based on LiF using unusual dopants. In a previous study our time presented results about thermoluminescence of pellets produced with this material, undoped [2] in this work we will show the firsts obtained with Dy, Eu, Nd and Tb as doping of LiF for use in thermoluminescent (TL) dosimetry. Initially, a study of the possibilities of preparation of LiF:Nd was carried by following others routes of preparation without sulphuric acid. After that, comparisons between the responses to beta radiation and x-ray were made using thermoluminescent techniques.

2. Methodology and Materials

The samples were prepared in the Laboratory of Materials Preparation and Characterization Department of Physics of Federal University of Sergipe. It was used LiF with chemical purity of 99% doped with 2% of EuO_3, NdO_3 and TbO_3, all them by Aldrich with purity of 99.9%. The composites were mixed with 10 ml of distilled water and taken to a magnetic agitator where they remained for 30 minutes. After that, drying took place in oven at a temperature of 100°C for 24 h. After the drying, the powder was homogenized again in mortar with the polyvinyl alcohol addition. The pellets were submitted to a uniaxial presage of 100 kgf/cm2 producing pellets of size 6mm diameter and 1mm thickness after sintering at temperatures of 650, 700 or 750°C for 1h, with a rate of heating of approximately 10°C per minute, and a free rate cooling down to room temperature.

The composites were irradiated with a beta source ($^{90}Sr+^{90}Y$). After each exposition, the pellets were submitted to thermal treatment at a temperature of 300ºC for 30 min. The measures of thermoluminescent were carried out up to 6 h after irradiation. TL measurements were made with a Harshaw 3500 thermoluminescent reader using a heating rate of 10°C/s.

The analysis of the homogeneity of chosen samples let witch the uncertainties in this study were always below 5%.

3. Results

In order to compare the influence of the sintering temperature it produced same pure LIF samples and of the dopant in the TL response it was initially prepared a set of pure LiF samples. Figure 1 shows the glow curves the pure LiF samples produced at 650, 700 and 750°C. TL emission of pure LiF pellets irradiated to 22.6 Gy with beta radiation exhibits two very well defined peaks around 170 and 250°C. The first TL peak was assumed as a dosimetric peak. The sintering at the 750°C has resulted in a more intense TL response to the absorbed dose.

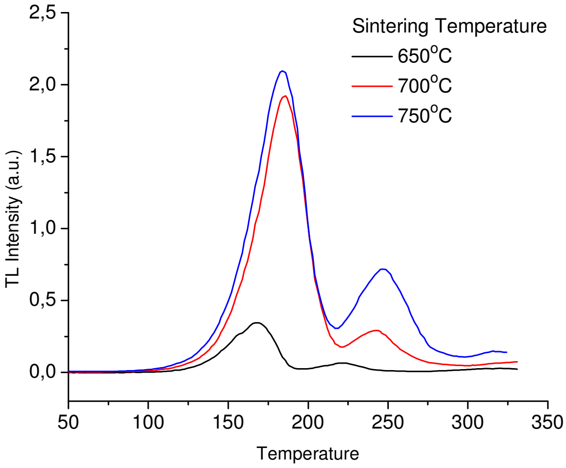

Figure 1. Typical TL emissions of LiF composites sintered at 650, 700 and 750°C beta irradiated (22.6 Gy, $^{90}Sr+^{90}Y$).

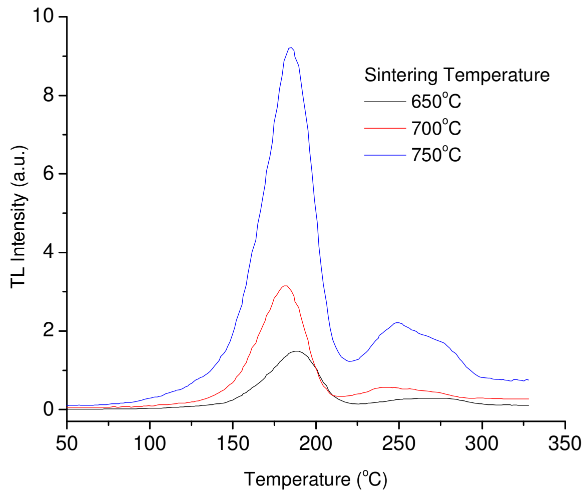

Figure 2. Typical TL emissions of LiF:Nd composites sintered at 650, 700 and 750°C beta irradiated (22.6 Gy, $^{90}Sr+^{90}Y$).

In figure 2, the TL emission curves of the LiF:Nd are compared regarding of sintering temperature influence in emission curves of the dosimeters The main difference between the TL emissions of the three composites irradiated with beta rays is in the TL intensities. The topaz composites sintered at 750°C displays a high sensitivity thermoluminescence as compared with the others. The shape of the emission curve is similar to the pure LiF. Meanwhile, they are bluish due to presence of the Nd and for the same absorbed dose, the TL intensity of the sample sintered in this temperature is four times higher than that one showed by pure LiF in the same produced in the same conditions. It is possible to observe too that the TL intensity of the peak of this emission is six times more intense than in pellet sintered at 650°C and three times when compares with pellet made at 700°C.

Figure 3 shows the dose response of LiF:Nd. This calibration curves presented responses proportional to absorbed dose between 0.5 Gy and 16.0 Gy for the beta radiation; the curves are useful in the whole tested dose range. No dose saturation was observed.

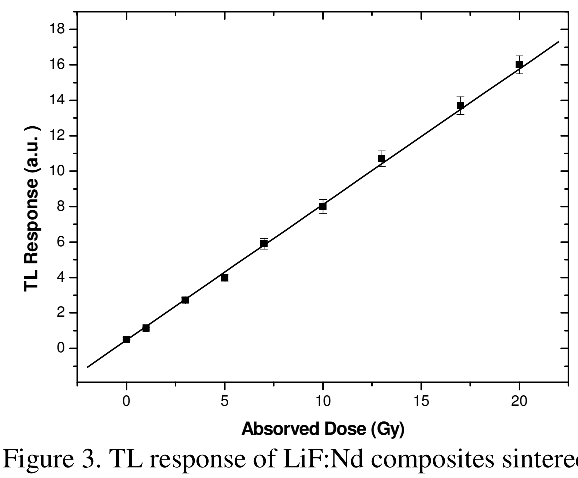

Figure 3. TL response of LiF:Nd composites sintered at 750°C beta irradiated in the range from 0.1 to 16 Gy.

The pellets doped with Eu sintered at 750°C exhibit a TL peak at 150°C witch has a low intensity if compared at the TL emission of LiF:Nd. In the same way the LiF:Dy not displays a performance of a good dosimetric material, although has shown a TL peak more intense and at higher temperature that the LiF:Dy (figure 4). The LIF:Tb (Figure 5) presents the lowest emission TL. Furthermore the glow curve presents many TL peaks probably due the colour of the pellets which was dark yellow.

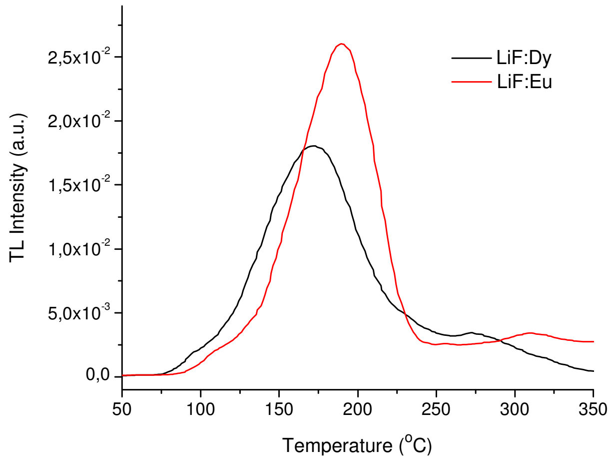

Figure 4. Typical TL emissions of LiF:Dy and LiF:Eu composites sintered at 750°C beta irradiated (11 Gy, ^{90}Sr+^{90}Y).

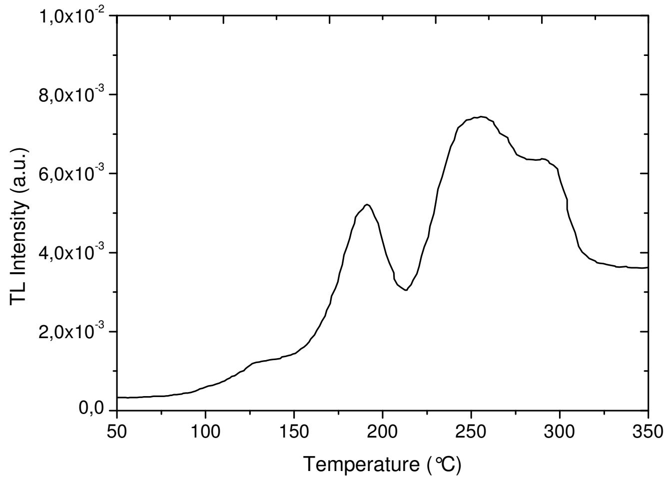

Figure 5. Typical TL emissions of LiF:Tb composite sintered at 750°C beta irradiated (11 Gy, ^{90}Sr+^{90}Y).

4. Conclusion

In this study it could be observed that the LiF doped with neodymium is a promising material for dosimetric purposes because presents a good response to dose and the temperature of occurrence of its higher peak is adequate o use in TL dosimetry. The other dopants, Dy, Eu and Tb, did not showed characteristics that could be useful to dosimetry in the dose range used in this work.

Due the previously mentioned properties associated with their low cost, the described detectors can be used in teaching laboratories as a complement of didactic practices involving the use of other kinds of radiation detectors, for example. Further techniques for preparation of the described composites, as well as other radiation sources for testing the pellets, can be within the scope of future works.

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