# Comparison of TL and OSL signal of LiF:Mg,Ti dosimeters to beta radiation

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**Abstract**
Due to the high sensitivity, good reproducibility, environmental stability and low fading thermoluminescent dosimeters (TLDs) are used in practical dosimetry. Different TL materials present most of these dosimetric requirements when applied to mainly mono-energtic radiation fields. Thermoluminescence (TL) is a process of stimulating, using thermal energy, the emission of luminescence from a substance following the absorption of energy from an external source by that substance [Yukihara and McKeever, 2011]. Optically stimulated luminescence (OSL) is a similar process than TL but, the luminescence is stimulated by the absorption of optical energy, rather than thermal energy [Yukihara and McKeever, 2011].
This work aims to compare the TL and OSL response of LiF:Mg,Ti pellets and micro dosimeters produced and manufactured by Harshaw, analysing its dose-response curves, reprodutibility and intrinsic efficiency to beta radiation. The TL and OSL response reproducibility was also analysed.

*Keywords:* lithium fluoride, thermoluminescence, optically stimulated luminescence, dosimetry, beta radiation.

## 1. Introduction

Thermoluminescence (TL) is a process of stimulating, using thermal energy, the emission of luminescence from a substance following the absorption of energy from an external source by that substance. Optically stimulated luminescence (OSL) is a similar process than TL but, the luminescence is stimulated by the absorption of optical energy, rather than thermal energy [Yukihara and McKeever, 2011].
The dosimetry of ionizing radiation is essential for the radiological protection programs for quality assurance and licensing of equipment. In radiotherapy treatments is necessary to be sure that the patient is receiving the correct prescribed dose and the main objective of dosimetry in radiotherapy is to determinate with greater precision the absorbed dose to the tumor [Metcalfe, Kron and Hoban, 2007].
The TLDs have a long history of ionizing radiation dosimetry and most measurements have been done with lithium fluoride doped with magnesium and titanium (LiF:Mg,Ti). It was perhaps the earliest material to be used in TL dosimetry following its development at the University of Winsconsin in the 1950s [Oster, Horowitz and Podpalov, 2010]. TLD are popular dosimeter in many hospitals for external dosimetry during radiotherapy treatment, however, the TLD can only provide an integral reading of the total surface exposure to the patient after treatment. On the other hand, OSL has the potential for the development of near-real-time dosimetry in wich the measured quantity can be either dose or dose rate [Bøtter-Jensen, McKeever and Wintle, 2003].
The use of OSL in medical dosimetry is growing. Properties as high sensitivity and the all-optical nature of the process are the two properties exploited most in medical dosimetry application. [Yukihara and McKeever, 2011]. The OSL response of LiF:Mg,Ti (TLD-100) dosimeters to alpha and beta particles to application to mixed-field radiation dosimetry was investigated by Oster et al by measuring the excitation and emission spectra of OSL and comparing with thermoluminescent (TL) characteristics [Oster, Horowitz and Podpalov, 2010]. Akselrod et al. (1999) demonstrated the ability to measure Hp(0.07) for low-energy radiation using OSL from $Al_2O_3$:C thin dosimeters [Akselrod et al.,1999]
This work aims to compare the TL and OSL response of LiF:Mg,Ti pellets and micro dosimeters, produced and manufactured by Harshaw, analyzing its dose-response curves, reprodutibility and intrinsic efficiency to beta irradiation. The TL and OSL response reproducibility was also analyzed.

## 2. Materials and Methods

### 2.1 Materials and Equipments

- ✓ 25 LiF:Mg,Ti dosimeters;
- ✓ 25 LiF:Mg,Ti microdosimeters;
- ✓ $^{60}$Co gamma source (656.4MBq);
- ✓ $^{90}$Sr/$^{90}$Y beta source (1.48 GBq);
- ✓ Furnace VULCAN model 3-550 PD;
- ✓ Furnace FANEN model 315-IEA 11200;
- ✓ TL/OSL Risø reader model TL/OSL-DA-20;
- ✓ Blue Led NICHIA - NSPB-500AS (470 nm);
- ✓ Hoya U-340 filter (7.5 mm thick, ø = 45 mm).

### 2.2 Methods

Before irradiations the dosimeters were heat-treated 400ºC/1h + 100ºC/2h using furnaces VULCAN model 3-550 PD and FANEN model 315-IEA 11200 respectively. To select the dosimeters according to their TL sensitivity, all dosimeters of LiF:Mg,Ti and microLiF:Mg,Ti were irradiated in air under electronic equilibrium conditions with a $^{60}$Co gamma source.

After the TL readings the individual and average TL responses of the dosimeters were obtained and they were separated into 10 groups of 5 detectors each according to their TL sensitivity (5 groups of LiF:Mg,Ti dosimeters and 5 groups of LiF:Mg,Ti microdosimeters).The selected dosimeters were irradiated with a $^{90}$Sr/$^{90}$Y beta source with doses ranging from 0.1 up to 10Gy. The beta source gives a dose rate of approximately 0.1Gy/s.

The beta irradiations and TL and OSL readings were done using a TL/OSL Risø reader model TL/OSL-DA-20, Figure1. The dosimeters were loaded onto an exchangeable sample carousel that can accommodate up to 48 samples. In the measurement position the sample can be stimulated thermally or optically. Thermal stimulation is obtained by linearly increasing the temperature of the heating element and optical stimulation is provided by different light sources focused onto the sample position. To OSL measurement the dosimeters were stimulated with Blue Led NICHIA - NSPB-500AS (470 nm) to OSL signal readings and for this measurement was used the Hoya U-340 filter.

The dose-response curve was obtained to 0.1, 0.5, 2.0, 5.0 and 10Gy.

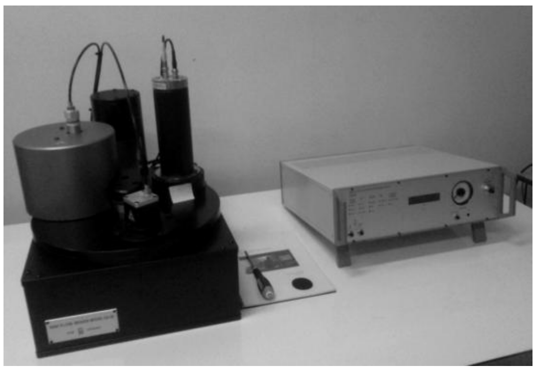

Fig. 1. TL/OSL reader Risø model TL/OSL-DA-20

Each presented value is the average of five measurements of dosimeters of the same sensitivity group and the error bars represent the standard deviation of the mean (1σ).The intrinsic efficiency (IE) and reproducibility were calculated with the respective equations 1 and 2:

$$IE = \frac{A}{m} \qquad (1),$$

$$\text{Reproducibility } (\%) = \frac{\sigma}{\sqrt{\text{n}} \cdot \overline{R}} \cdot 100 \qquad (2),$$

where: “A” is the slope of the adjusted line provided by the Origin 8.0 program, “m” is the dosimeter mass, “σ” is the standard deviation, “n” is the number of dosimeters and “$\overline{R}$” is the mean of the TL/OSL response of the dosimeters of each group.

## 3. Results

The TL and OSL dose-response curves of LiF:Mg,Ti and microLiF:Mg,Ti dosimeters to beta radiation to the absorbed doses range studied (0.1 – 10Gy) are shown in the Figure 2 and 3 respectively.

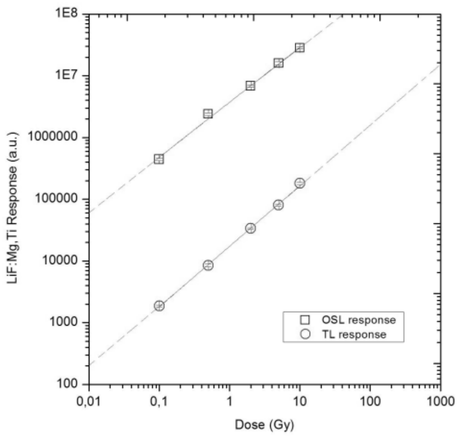


Figure 2. TL and OSL dose–response curves of the LiF:Mg,Ti dosimeters to beta radiation

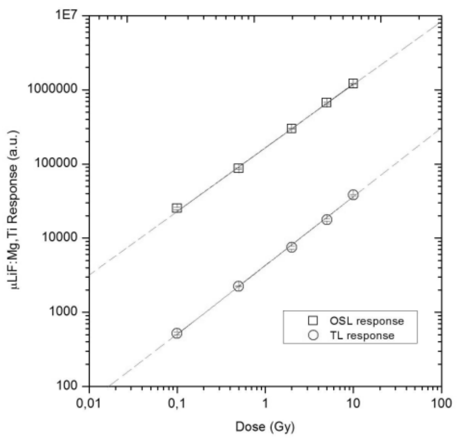


Figure 3. TL and OSL dose–response curves of the microLiF:Mg,Ti dosimeters to beta radiation

The dose-response curves show a linear behavior in the beta absorbed dose range studied (0.1 to 10 Gy) for TL and OSL techniques and both dosimeters.

The Table 1 present the calculated intrinsic efficiency and the reproducibility of LiF:Mg,Ti and microLiF:Mg,Ti dosimeters to beta radiation to the different techniques.

Table 1. Intrinsic efficiency and the reproducibility of LiF:Mg,Ti and microLiF:Mg,Ti dosimeters to TL and OSL technique to beta radiation.

| | LiF:Mg,Ti | | microLiF:Mg,Ti | |
|---|---|---|---|---|
| | TL | OSL | TL | OSL |
| Intrinsic Efficiency (units.$Gy^{-1}$.$mg^{-1}$) | 0.49 ± 0.05 | 0.45 ± 0.04 | 0.92 ± 0.09 | 0.86 ± 0.08 |
| Reproducibility (%) | ≤ ± 1.91 | ≤ ± 2.74 | ≤ ± 1.62 | ≤ ± 2.22 |

To LiF:Mg,Ti dosimeters the intrinsic efficiency obtained using TL and OSL technique was 0.49 ± 0.05 04 units.$Gy^{-1}$.$mg^{-1}$ and 0.45 ± 0.04 units.$Gy^{-1}$.$mg^{-1}$ respectively and to microLiF:Mg,Ti dosimeters the intrinsic efficiency obtained was 0.92 ± 0.09 04 units.$Gy^{-1}$.$mg^{-1}$ and 0.86 ± 0.08 units.$Gy^{-1}$.$mg^{-1}$ to TL and OSL technique respectively.

About the reproducibility of LiF:Mg,Ti dosimeters, it's better than ± 1.91% and ± 2.74% to TL and OSL technique respectively and to microLiF:Mg,Ti dosimeters, the reproducibility is better than ± 1.62% and ± 2.22% to TL and OSL technique respectively.

**4. Conclusions**

In the dose range studied the dose-response curves of LiF:Mg,Ti and microLiF:Mg,Ti presents linear behavior to TL and OSL techniques. The TL and OSL intrinsic efficiency of microLiF:Mg,Ti is approximately 1.9 times higher than LiF:Mg,Ti and the reproducibility of LiF:Mg,Ti and microLiF:Mg,Ti is in accordance with the literature (< ± 5%) to OSL and TL technique.
The obtained results indicate the viability of application of the LiF:Mg,Ti and microLiF:Mg,Ti dosimeters in TL and OSL beta dosimetry.

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