

## Evaluation of a LiF:Mg,Ti thermoluminescent ring dosimeter according to the IEC 62387:2012 Standards

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**Abstract:** This work shows results of type testing of a ring dosimeter system under new IEC 62387:2012. The personal dosimeter investigated in this work consists of a commercial one element plastic ring (RADOS) which contains an LiF:Mg,Ti. By applying requirements for statistical fluctuations and linearity, a minimum measurable dose in Hp(0.07) was established. Energy and angular dependence aided in determining energy correction factors and fading requirements were used to select the most appropriate preheat scheme. Type testing of passive radiation monitors performed in the Radiation Metrology Laboratory (LMRI-DEN/UFPE) of the Federal University of Pernambuco is a major step in Brazil for the independent evaluation of these dosimeters, currently not available in the country.

**Keywords:** passive radiation monitoring, ring dosimeter, IEC 62387:2012

### 1. INTRODUCTION

Due to an increasing demand for extremity radiation dosimetry for medicine, the Radiation Protection Laboratory (LPR-DEN/UFPE) of the Federal University of Pernambuco has been investigating an appropriate system for ring dosimetry. There are few publications on testing of ring dosimeters according to newer IEC 62387:2012 [1] standards. Reports [2,3] usually are based on older ISO 6280 [4] ISO/DIS 12794-1[5] standards. The scope of this paper is to present the results down to the limits of acceptability of tests performed on a commercial ring dosimeter (RADOS) with LiF:Mg,Ti crystals according to the IEC 62387:2012 [1] standards for Hp(0.07) (personal dose equivalent for 0.07 mm depth). Testing was independently performed in the Radiation Metrology Laboratory

(LMRI-DEN/UFPE) of the Federal University of Pernambuco.

### 2. DOSIMETRY SYSTEM DESIGN

The personal dosimeter investigated in this work consists of a commercial one element plastic ring (RADOS) which contains an LiF:Mg,Ti with 4.55 mm in diameter (MTS, Poland) detector and 0.93 mm in thickness. The front cover of the ring has a measured thickness of 0.38 mm. Figure 1 shows the front and back covers of the ring and the TL element placement on the back cover. The back cover has a wall thickness surrounding the edge of the crystal with 0.98 mm in thickness.

Measurements were performed in a Harshaw-Bicron 3500 TL reader using 165 °C / 16 s pre-heat. Indicated values were corrected for individual element sensitivity variations (Element

Correction Factors) and Reader Calibration Factors.

**Figure 1.** Ring dosimeter front and back covers.



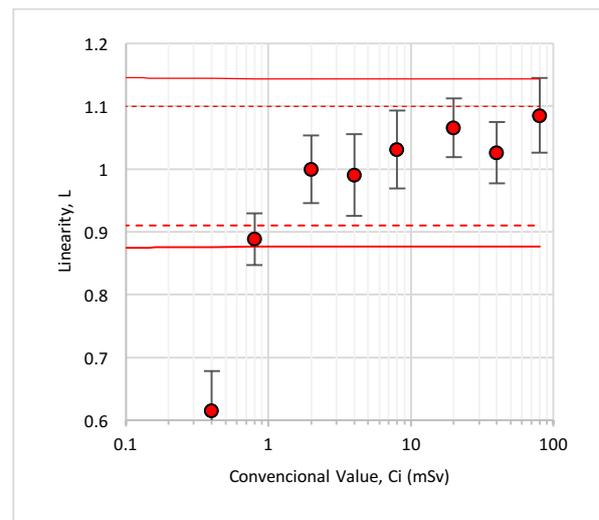
### 3. NON-LINEARITY AND STATISTICAL FLUCTUATIONS

IEC 62387:2012 [1] requires that statistical fluctuations of the indicated value to be performed together with the testing of non-linearity. A total of  $w = 10$  dose values with  $n = 7$  dosimeter per group were tested. Irradiations were performed on a rod phantom using Hp(0.07) values of 0.2 mSv to 80 mSv. Figure 2 shows the results and the required limits (solid lines). The maximum coefficient of variation (CV) of 24% was found for the dose value of 0.2 mSv which is just outside of the 23% limit. All other CV values are within the  $c_1/c_2$  corrected limiting values of  $(16 - H/0.1 \text{ mSv}) \%$  for Hp(0.07) values within 0.1 and 1.1 mSv and 5% for values higher than 1.1 mSv [1].

The results for linearity (Figure 2) show that values above 1.0 mSv are considered acceptable. The two lowest values of 0.2 and 0.4 mSv were outside the limits due to proximity to background, which consists of nearly 50% of the raw reading at these low dose values. By using the IEC linearity criteria, instead of the commonly used 3 standard deviations above background, the minimum measurable dose was set to 1.0 mSv. Since dose limits for skin, hands and feet are 500

mSv/yr, and Investigation Limits in Brazil are set to 20 mSv/month according to national regulations [6], this value is considered acceptable.

**Figure 2.** Linearity and statistical fluctuations results. Dashed and solid line limits are the required limits without and with the uncertainties for irradiation, respectively.



### 4. ENERGY AND ANGULAR RESPONSE

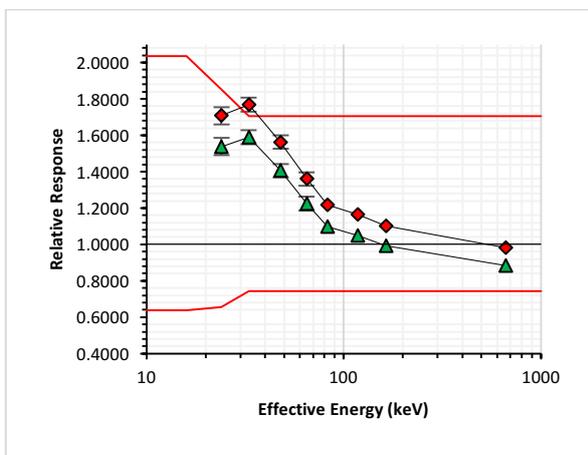
LiF:Mg,Ti has an energy dependence that must be corrected using an appropriate algorithm in order to assess the Hp(0.07) dose values over the rated energy range within acceptable tolerances. An algorithm for a single element dosimeter consists of a multiplying factor.

Testing was performed using  $n = 6$  dosimeters per energy value in the range between 20 keV (ISO N30) and S-Cs-137 quality. Figure 3 shows the results of the energy dependence of the ring dosimeters and the IEC 62387:2012 acceptance criteria (red solid lines). The upper curve refers to the values using ECC and the reader calibration factors for Cs-137 energy. An energy correction factor  $f_E$  of 0.90 (lower curve in Figure 3) is a sufficient correction so the values are within the

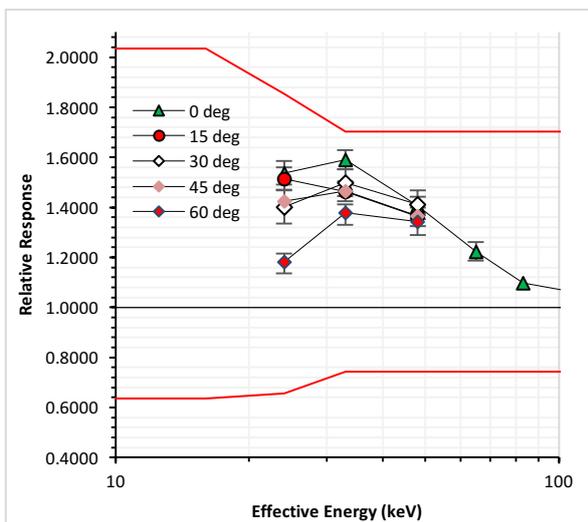
IEC acceptable limits, over the energy range from 20 keV to 662 keV.

Angular dependence of the ring dosimeters was assessed at 0°, 15°, 30°, 45° and 60° and for the three lowest effective energies (20, 24 and 33 keV). The results are within the IEC requirements [1], as shown in Figure 4.

**Figure 3.** Energy dependence of the ring dosimeters with an energy dependence factor applied (lower curve) and without (upper curve).



**Figure 4.** Angular and energy dependence of the ring dosimeters.



## 5. OVER RESPONSE TO SIDE IRRADIATION

The assessment of the overresponse due to side irradiation prevents the acceptance of a detector with high atomic number without sufficient shielding [1]. Dosimeters were irradiated free using an H\*(10) of 3 mSv in air from 60° to 120° ( $\alpha_{\max} = 60^\circ$ ) for Cs-137 and for the three lowest energies (20, 24 and 33 keV). Side irradiation and the over response is required to be within 2.0 times of the response at 0° for Hp(0.07).

Since LiF:Mg,Ti has a low energy dependence an over response was not found but instead a decrease in the response as the angle is varied from 60 to 120°. For Cs-137 gamma rays a decrease of -8% was found, followed by a 12% decrease for 33 keV (N60), 29% for 24 keV (N40) and up to 46% for 20 keV (N30). These results meet the IEC requirements. The decrease in response observed can be explained by the fact that the back/side cover of the dosimeter is thicker than the front cover (see Figure 1) and shields more effectively the lower energy photons.

## 6. DOSE BUILD-UP, FADING, SELF-IRRADIATION AND NATURAL IRRADIATION

The relative response and deviation due to dose build-up and fading is tested using eight groups of dosimeters. Groups 1 to 3 (n=6 each) were irradiated at an Hp(0.07) of 7 mSv and Group 4 (n=25) with 1 mSv. Groups 5 to 7 (n=6 each) and 8 (n=25) were reserved for background measurements. Groups 1 to 5 were read out at 1 h after irradiation and Groups 2 and 6 after one week. Groups 3, 4, 7 and 8 were read after one month. For these measurements a preheat of 160 °C/16s was used. Results showed that the response is better than 2% and therefore within the 0.91 to 1.11 tolerance limit [1].

In addition to these tests, it is known that due to shallow trap instability in LiF:Mg,Ti at room temperature that an appropriate preheat is necessary prior to the dose measurement. In order to evaluate the appropriateness of preheat schemes with respect to IEC requirements, three different preheats were tested at 1h and at 7 days after irradiation: (a) 160 °C/16s; (b) 150 °C/16s; and (c) 160 °C/10s.

The results showed a small 0.7 % decrease in response for the 160 °C/16s preheat scheme after 7 days; followed by a 4.7% decrease for 160 °C/10s; and a 7.7% decrease for 150 °C/16s. Therefore the 160 °C/16s preheat was considered more appropriate for routine use.

## 7. CONCLUSIONS

The assessment of the dosimeter ring system was considered appropriate, according to IEC 62387:2012 for  $H(0.07)_{low} \geq 1.0$  mSv, which is considered appropriate for extremity dose evaluations. IEC Standards also aided in the refinement of the dose algorithm by determining energy correction factors within the stated range and preheat setups.

The implementation of type testing of passive radiation monitors performed in the Radiation

Metrology Laboratory (LMRI) of the Federal University of Pernambuco is a major step in Brazil for the independent evaluation of these dosimeters, currently not available in the country.

## 8. REFERENCES

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