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Dosimetric evaluation of thermoluninescent LiF:Mg,Ti and $CaSO_4$:Dy dosimeters and LiF microdosimeters for application in in vivo dosimetry of clinical electron beams.

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ABSTRACT

The verification of the patient dose has been recommended to improve the quality of radiotherapy treatment by various organizations such as AAPM (American Association of Physicists in Medicine) and ESTRO (European Society of Therapeutic Radiology and Oncology). The in vivo dosimetry has become an important part in the program of quality assurance (QA) in the departments of radiotherapy and has proved very useful in determining the dose applied to a particular patient, as well as detection of various types of errors in the dose process application. Thermoluminescent dosimeters (TLD) play an important role in radiation dosimetry and present advantages that make them useful for in vivo dosimetry in patients. This paper aims to evaluate the performance of LiF microdosimeters and LiF: Mg,Ti and $CaSO_4$: Dy dosimeters in ^{60}Co gamma field and select the detectors groups which present TL response with sensitivity and reproducibility better than ± 5%. It is expected a standardized method of employing the termoluninescent dosimetry technique and development of a dosimetric system in accordance with the international recommendations.

1. INTRODUCTION

Electron beams of high energy (> 5 MeV) have a broad application in medicine, especially in the treatment of several types of cancer. The application of electron in therapy requires great accuracy in the dose absorbed by the tumor, as a variation of ± 5% is determining the risk of recurrence or sequel [1]. This, therefore, requires measure and strict control of the dose using dosimeters which have high accuracy and precision in the measures.

The most useful dosimeters for clinical electron beams are the ionization chamber [2,3,4], Fricke dosimeters[5] and thermoluminescent dosimeters[4,6,7,8]. The high sensitivity of the thermoluminescent materials allows the construction of dosimeters resistant and applicable in various shapes and sizes, including small sizes, which makes them a useful tool, particularly for measurements in regions of acute dose gradients[9] for in vivo dosimetry [10].

In radiotherapy, the majority of measures, using thermoluminescent dosimeters have been made using the lithium fluoride (LiF), generally the TLD-100, marketed by Harshaw, which already has a long history in this type of application [11,12]. More recently, it has been characterized and used the microdosimeters of LiF, which are similar to detectors TLD-100,

but with dimensions of 1x1x1 mm^3. The minimum dimensions allow its use with some advantages, especially in in vivo monitoring.
Other thermoluminescent material, the $CaSO_4$: Dy, has been intensively used in measures of radioprotection and environmental dose-levels [12,13] due to its high sensitivity. This material presents a wide range of linearity of response to radiation, which goes from mGy to Gy [12], and has been evaluated for other applications related to radiation, mainly involving electron beams [14]. The $CaSO_4$: Dy is manufactured and marketed by Laboratório de Materiais Dosimétricos of the Centro de Metrologia das Radiações/IPEN[15].

2. MATERIALS AND METHODS

The study includes several steps prior to exposure the dosimeters to electron beams, as is required with the selection of detectors which present sensitive and reproducible TL response. A batch of 200 LiF:Mg,Ti (TLD-100) and 200 $CaSO_4$:Dy dosimeters and 105 LiF microdosimeters were selected to be evaluated and the TL responses compared.

Heat treatment: For the LiF dosimeters, the heat treatment consisted of two steps, 1hour at 400 ºC followed by 2 hours at 100 ºC. In this case, in which the heat treatment involved two heater systems, one furnace and one surgical stove respectively, the dosimeters were fast cooled to ambient temperature at the end of the first heating treatment and then placed in preheated stove for the second step. The heat treatment for $CaSO_4$:Dy pellets consisted of 3 hours at 300°C.

Gamma Radiation irradiation: After the heat treatment the dosimeters were irradiated with cobalt-60 gamma radiation , used as standard source, free in air, at electronic equilibrium conditions and 34 cm source-dosimeter distance. The applied doses used to sensitivity selection and batch calibration were: 1.735 mGy for LiF (TLD-100), 1.729 mGy for CaSO4:Dy and 0.690 mGy for LiF microdosimeters. The schematic diagram of the cobalt-60 radiation source is presented at Figure 1.

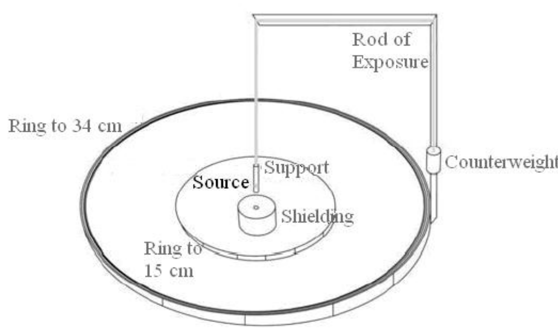

Figure 1: Schematic diagram of the cobalt-60 radiation source.

Reading the signal TL: The dosimeter is placed on the metallic planchet of the TL reader Harshaw model 3500 and heated by contact, giving rise to the TL signal. The applied voltage was always 677 V. For evaluation of the TL signal of $CaSO_4$:Dy dosimeters the protocol number 9 was used, defined by the user. The temperature of the heating system during the acquisition data was between 50°C to 350°C at a heating rate of 10°C.s^{-1}; remaining at 350°C for more 6,66 s. The protocol number 3 was used to assess the TL signal of LiF and micro LiF samples. This protocol differs from that defined for the $CaSO_4$:Dy in the temperature of 300°C and the total time of 33,33 s, to acquisition of the TL signal.

3. RESULTS AND DISCUSSION

The values obtained by reading the different dosimeters were plotted in a graph with its limits of acceptability (± 5%) and are represented in Figures 2, 4 and 6. The histograms can be seen in Figures 3, 5 and 7. The importance of examining correctly both, reading graphs and histograms, is because the need for a homogeneous batch of dosimeters, which have very similar sensibilities.

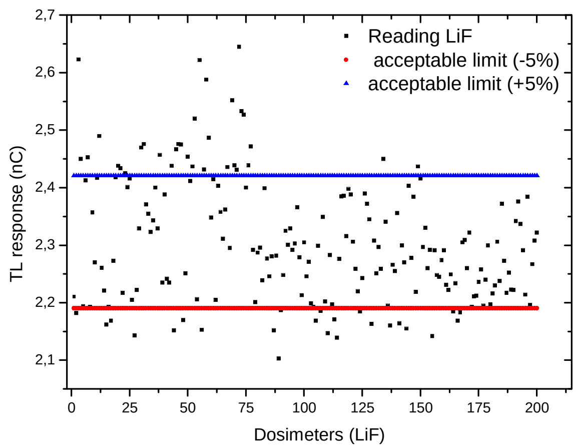

Figure 2: TL response of 200 LiF (TLD-100) dosimeters.

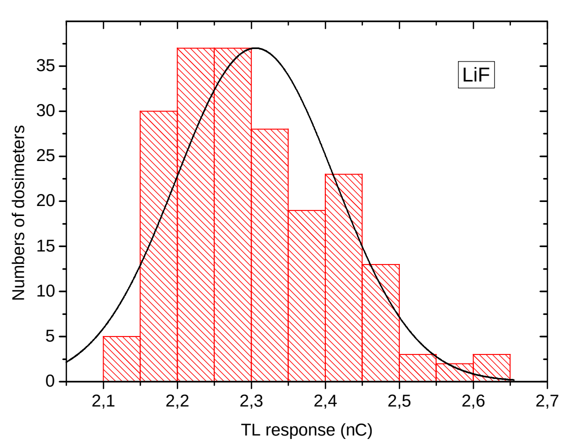

Figure 3: Histogram of the TL response of 200 LiF (TLD-100) dosimeters.

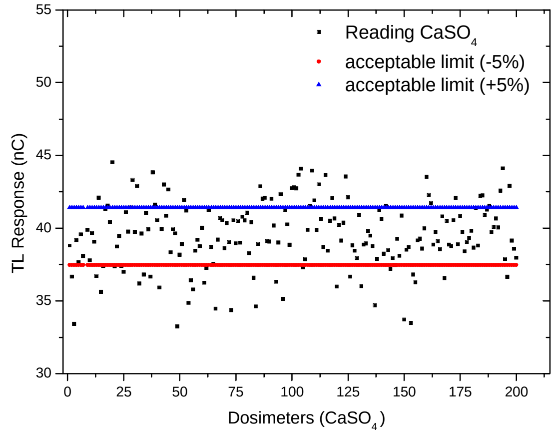

Figure 4: TL response of 200 dosimeters of $CaSO_4$ dosimeters.

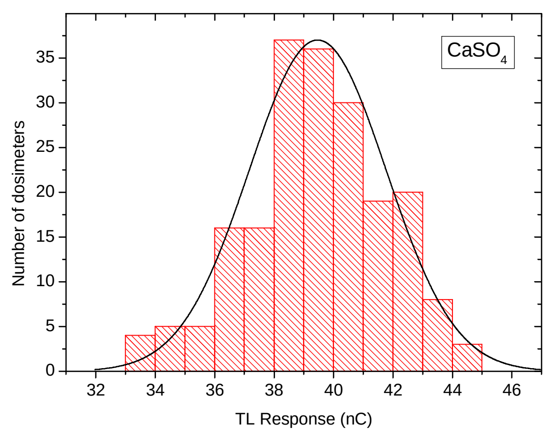

Figure 5 : Histogram of the TL responses of 200 $CaSO_4$ dosimeters.

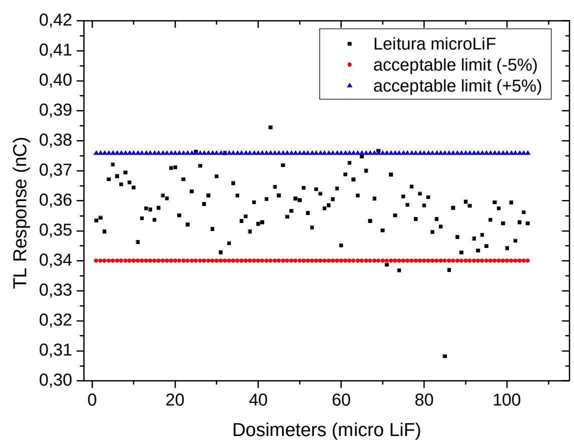

Figure 6: TL response of 105 LiF microdosimeters.

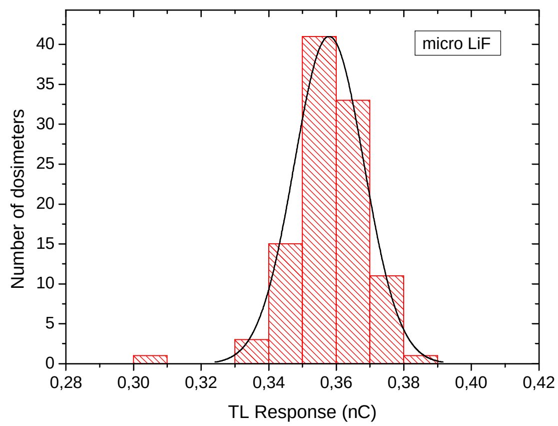

Figure 7: Histogram of the TL responses of 105 LiF microdosimeters.

With the analysis of graphs and histograms the dosimeters that had values outside the range of reading were discarded and thus was evaluated a new batch of chips containing 152 LiF (TLD -100) dosimeters, 140 $CaSO_4$ pellets and 101 LiF microdosimeters. The selection was made with attention to care so that the experimental uncertainties involved were minimized. The sets of dosimeters were obtained with maximum uniformity in the TL response. In the next step the selected dosimeters will be divided into lots and irradiated with electron beams of different energies using simulators of acrylic, water and solid water with thickness ranging from 5 to 30 mm. The field size will be 15 x 15 cm^2 and the source – dosimeter distance 100cm. The dose-response curves, surface dose and depth dose will be evaluated. The TL electron energy response dependence and the influence of simulator materials will also be studied.

4. CONCLUSION

The careful selection of dosimeters is essential to the accuracy of the results obtained in the electron beam irradiation. The small size and wide range of measurable dose of the dosimeters are fundamental advantages to using them in places where you can not practice another form of dosimetry. The obtained results indicate that the selected dosimeters can be used to potential clinical applications.

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