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TL response study of the $CaSO_4$: Dy pellets with graphite for dosimetry in beta radiation and low-energy photons fields

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Abstract

The $CaSO_4$: Dy is a good thermoluminescent dosimeter because of its high sensitivity and low cost. With graphite in the pellets it is possible to reduce the energy dependence. The sensitivity and energy dependence of the different thicknesses of $CaSO_4$: Dy pellets was studied with different amounts of graphite. The results have shown the optimal quantity of the graphite and the appropriate thickness of the pellets that can be used in dosimetry of beta field, photons or both simultaneously.

Keywords: Pellets of $CaSO_4$: Dy + Teflon; TLD response; TLD sensitivity

1. Introduction

In most recent studies of $CaSO_4$: Dy as a dosimetric material the researchers have shown that it, is adequate for measurements in the photon fields, when the material is in pellet form with 0.8 mm of thickness. The beta fields dosimetry requires smaller thicknesses (μm) to measure dose compared with the photon fields, as demonstrated by Da Rosa and Caldas (1986); Da Rosa et al. (1986) and Nagpal et al. (1993). Considering that this material might be a good radiation detector, it is necessary to reduce the dependence of TL response in the function of the energy of the incident radiation. Horowitz (1984) and Pradhan and Bhatt (1977) have proposed that it is possible to reduce this dependence with addition of graphite in the manufacturing process. With the addition of graphite during the production process of the pellets, it is possible to decrease the energy dependence, although the inherent sensitivity is also reduced. The presence of graphite in the dosimeter has no effect on the TL characteristics of the phosphor, and it is possible to keep the same mechanical strength offered by the dosimeters without graphite. This is in agreement with results obtained by Campos (1993) and Horowitz and Yossian (1995).

A personal dosimeter for application in mixed beta–gamma fields requires a thin detector with an appropriate sensitivity and a mechanical strength suited for handling (Da Rosa et al., 1996). $CaSO_4$: Dy is accepted as a good thermoluminescent material in environmental dosimetry due to its high sensitivity, low cost and its ability to be easily manufactured (Campos, 1988).

In the last few years, pellets of $CaSO_4$: Dy + Teflon with different thicknesses (0.2H, 0.4, 0.6 and 0.8 mm) have been produced and studied by the IPEN laboratories In this work, the sensitivity and energy dependence of the TL response of $CaSO_4$: Dy + Teflon pellets were studied with different amounts of graphite.

2. Objective

The purpose of this study is to characterize the TL response of the $CaSO_4$: Dy + Teflon pellets with differ-

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ent thicknesses (0.2, 0.4, 0.6 and 0.8 mm) and different quantities of graphite added in the Teflon mass (0, 0.5, 1, 3, 5, 10 and 20%), in order to find out which of these dosimeters can be used in dosimetry of beta fields, photons or both simultaneously.

3. Materials and method

Sintered TLD pellets of different thicknesses were obtained from homogeneous mixture of $CaSO_4:Dy$, Teflon powder and graphite (0, 0.5, 1, 3, 5, 10 and 20% by weight), using the relation

$$M = 1/3 M_{CaSO_4:Dy} + 2/3(M_t + M_g),$$

where M is the total mass of a pellet; $M_{CaSO_4:Dy}$ is the mass of the $CaSO_4:Dy$ powder; M_t and M_g are the Teflon and graphite powder, respectively. Each p% of the graphite was made with amounts of 20, 30, 40 and 50 mg of the total mass, resulting in samples of 0.2, 0.4, 0.6 and 0.8 mm of thickness with different quantities of graphite.

The powder of the $CaSO_4:Dy$ was produced in IPEN laboratory using crystal with grain size varying from 75 to 175 μm. Luguerra et al. (1990) had shown that this size is adequate to be used in the photons and beta fields. The Teflon powder trade mark is Du Pont with 165 μm grain size.

The pellets of this mixture, with a diameter of 6 mm and thicknesses between 0.2 and 0.8 mm were first cold pressed and then sintered. This method was used for 700 pellets which were distributed in 28 groups each group containing 10 pellets of the same kind.

The beta doses were carried out using a beta Secondary Standards System with $^{90}Sr/^{90}Y$, ^{204}Tl and ^{147}Pm sources; the photon irradiations were carried out using a ^{60}Co (1 GBq) and the X-ray generated by a therapy equipment Westinghouse in energies of 14.1 and 92.5 keV. The samples were always irradiated under electronic equilibrium conditions.

The TL response was determined using the Harshaw TL reader model 4000. The linear heating rate was set at $10°C\,s^{-1}$; and the reading cycle was performed within 36 s, with a constant nitrogen flux of $1.5\,L\,min^{-1}$. Light emission was integrated in the temperature interval between 180 and 350°C. Prior to irradiation, the samples were submitted to annealing at 300°C for 3 h. They were irradiated in the air under the same geometric conditions. Each reported value corresponds to the average value of ten measurements.

4. Results

4.1. Photon response

The $CaSO_4:Dy$ + Teflon pellets with different graphite contents were exposed to ^{60}Co gamma radiation and X-ray energies 14.3, 21.2, 31.2, 37.3, 64.4, 74.5 and 92.3 keV and the results of energy dependence of all types of $CaSO_4:Dy$ pellets can be seen in Fig. 1. The decrease of the TL sensitivity related to the increase of the graphite content was the same for all studied thicknesses. One example is shown in Fig. 2, to the ^{60}Co energy gamma irradiation and the pellets with 50 mg.

From Fig. 3 it can be observed that the TL response for thicknesses lower than 0.4 mm varies. This variation becomes less as the graphite percentage increases. For low-energy photon dosimetry it is, therefore recommended to use thicknesses larger than 0.6 mm (40 mg) they are able to produce a balanced photoeletron emission with the TLD emission, due to the primary photon penetration power.

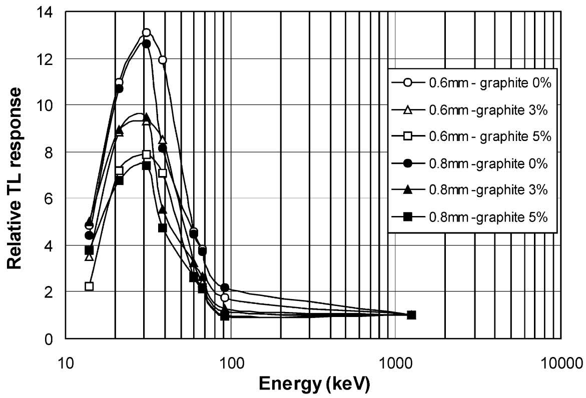

Fig. 1. Photon energy relative TL response curve of graphite mixed and pure TL dosimeters with 0.6 and 0.8 mm thick, respectively (40 and 50 mg).

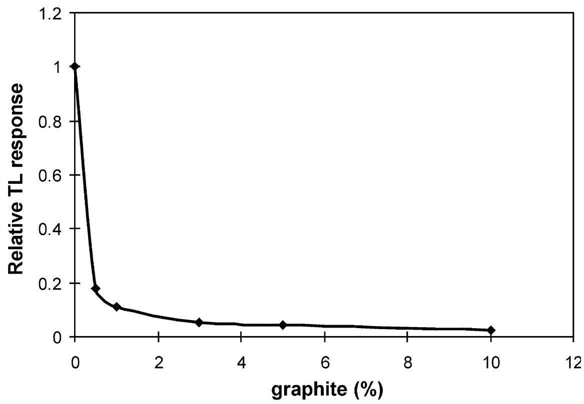

Fig. 2. Decrease of the relative TL response of pellets with 0.8 mm and different amounts of graphite, when irradiated with ^{60}Co gamma radiation.

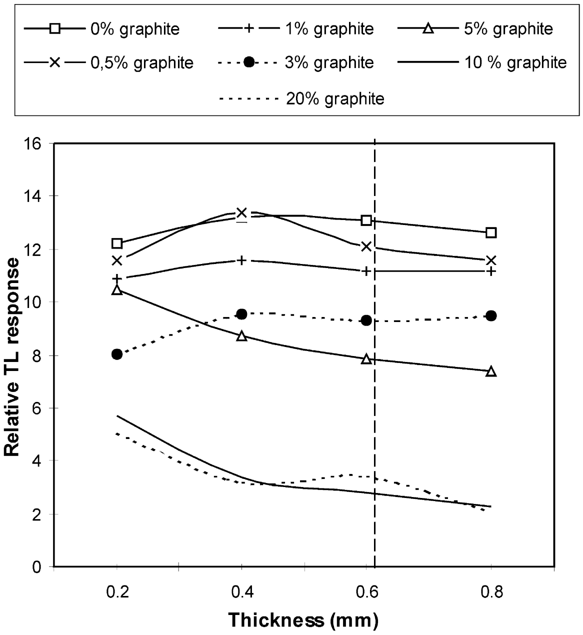

Fig. 3. Relative TL response as a function of pellet thickness and graphite content to 31.2 keV photon field.

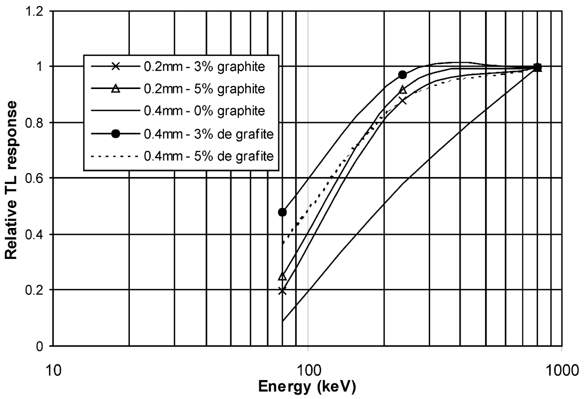

Fig. 4. Beta energy relative TL response curve of graphite mixed and pure TL dosimeters with 0.2 and 0.4 mm thick, respectively (20 and 30 mg), to photons with 31.2 keV.

4.2. Beta response

The $CaSO_4:Dy$ + Teflon pellets with different graphite contents were irradiated with $^{90}Sr/^{90}Y$, ^{204}Tl and ^{147}Pm beta fields. The results of the energy dependence of all types of $CaSO_4:Dy$ can be observed in Fig. 4.

The decrease of the TL sensitivity with the increase of the graphite content was comparable to the photon results.

The relation of different quantities of graphite as a function of the mass of the pellets has shown that thin

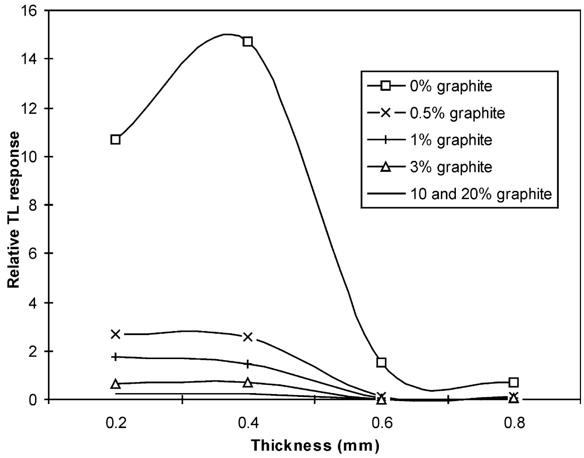

Fig. 5. Relative TL response as a function of pellet mass and graphite content to beta field, when irradiated with $^{90}Sr/^{90}Y$ beta radiation.

detectors are appropriate for beta fields applications and thicknesses smaller than 0.4 mm (30 mg) are the best ones as demonstrated by the graph of Fig. 5.

5. Discussion and conclusion

The sensitivity of $CaSO_4:Dy$ + Teflon with 3 and 5% graphite contents decreased 90% when compared with the pellets without graphite for all kinds and energy radiation fields. The results are similar to those obtained from Pradhan and Bhatt (1977). The energy dependence of beta radiation on pellets with 3% graphite contents and 0.4 mm thickness, decreased 33.3 and 65% for 100 and 240 keV, respectively. There is no significant energy dependence for energies above 300 keV. The energy dependence of photon radiation on pellets with 5% graphite content and 0.8 mm thickness, decreased 54% for 30 keV.

The relative TL response for beta radiation is independent of the mass of the pellets when graphite is added in pellets smaller than 0.3 mm thick. The relative TL response for photon fields is stable when the pellets thickness is higher than 0.6 mm, with or without graphite content.

The optimal TL response for the beta fields was obtained for 0.4 mm thick pellets with 3% of graphite content, since the photon fields of 0.8 mm thickness with 5% of graphite content were the most appropriated. It is possible to conclude that to evaluate mixed fields (gamma and beta) it is necessary to use both kinds of pellets.

The American National Standards Institutes (ANSI), has done environmental surveillance program as a pilot test for beta and low-energy phantoms for monitoring programs. The results have pointed to the importance of the environmental dosimetry programs in order to assess radiation dose to the general public (Klemic et al., 2000).

The graphite mixed $CaSO_4:Dy+$Teflon pellets studied in this work could be an attractive detector for beta as well as gamma or mixed-field dose measurements, since they present smaller energy dependence on beta and photon fields.

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