Study of crystalline $BaSO_4$:Eu using the thermoluminescence technique

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Abstract: In this work, the dosimetric properties of $BaSO_4$:Eu samples doped with several different concentrations of Eu were evaluated (0.05%, 0.1%, 0.2% and 1.0%) utilizing the thermoluminescence technique. The $BaSO_4$:Eu samples were synthesized by the chemical co-precipitation method. The main dosimetric properties of the $BaSO_4$:Eu samples determined in this work were: dose-response curves to gamma radiation (^{60}Co), response reproducibility and lower detection limits. The TL peak, for all Eu concentrations, appeared at approximately 223°C. It was also possible to observe a decrease of the TL response with the increase on the dopant concentration.
Keywords: thermoluminescence, ^{60}Co gamma rays, $BaSO_4$:Eu.

Introduction

Ionizing radiation dosimetry is very important in several fields such as diagnostic radiology, radiotherapy, nuclear medicine, geological and archaeological dating methods, food preservation, sterilization of pharmaceutical products and treatment of several materials. There are several detectors that can be applied in ionizing radiation dosimetry; the most widespread technique is thermoluminescence (TL). Using the TL technique, several materials were studied, but the most utilized are LiF and $CaSO_4$ [1].

In this work, the dosimetric properties of $BaSO_4$:Eu samples doped with several different concentrations of Eu were evaluated (0.05%, 0.1%, 0.2% and 1.0%) utilizing the TL technique.

Experimental Procedure (or Computational Procedure)

The $BaSO_4$:Eu samples were synthesized by the chemical co-precipitation method. In this method, the analytical reagent grade Barium chloride ($BaCl_2$) was dissolved in double distilled water. The Europium chloride ($EuCl_3$) was obtained by Europium oxide (Eu_2O_3): in an aqueous solution in concentrated hydrochloric acid (HCl), the mixture was maintained in heating at 80ºC to obtain a pH value of 4.5–5.5. The solution was dried in a water bath for crystal formation. This salt was maintained in a desiccator, and weighed and added in sufficient amounts to obtain 0.05%, 0.1%, 0.2% and 1.0% solutions of $BaCl_2$.

The different solutions were then mixed with a solution of ammonium sulfate $(NH_4)_2SO_4$ stoichiometrically in the presence of ethanol. The solution of $(NH_4)_2SO_4$ was slowly added to $BaSO_4$ solution until complete precipitation. The precipitate was washed three times with distilled water. The crystals were finally obtained by drying the precipitate at 110ºC for 4 h. Part of the samples were submitted to a sintering process using the calcination technique. During the calcination method, the $BaSO_4$:Eu samples were maintained at the temperature of 500ºC during 2 hours, in a furnace (model EDG10P-S (7000)). Finally, the sintered pellets were prepared, using Teflon as binder, and the parts were mixed in the ratio 2 (Teflon):1 (powdered sample) in open atmosphere nitrogen, to facilitate its handling. This mixture was cooled with liquid nitrogen to optimize the homogenization. These pellets are 6.0 mm in diameter by 2.0 mm in thickness, and they present 50.0 mg of mass.

The samples were irradiated using a Gamma Cell-220 System of ^{60}Co (dose rate of 1.258 kGy/h). To obtain electronic equilibrium the samples were fixed between two plates of polymethyl methacrylate (PMMA) with thickness of 3.0 mm. The irradiations were undertaken at ambient temperature. The OSL and TL measurements were taken using a RIS¨O TL/OSL Reader and Controller, model DA-20, and the data acquisition was realized using a personal computer. For reutilization, the pellets were thermally treated at 300ºC/1h.

Results and Discussion

The TL glow curves of $BaSO_4$ doped with different concentrations of Eu are shown in Figure 1. The TL peak, for all Eu concentrations, appeared at approximately 223ºC. For all TL measurements a heating rate of 10ºC/min was utilized. All samples of $BaSO_4$ dopped with Eu presented suitable responses, and they show potential use for gamma high-dose dosimetry. It was also possible to observe a decrease of the TL response with the increase on the dopant concentration.

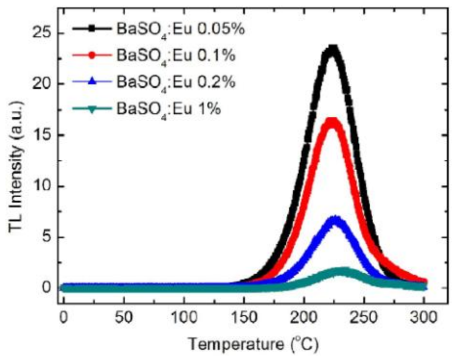

Figure 1: TL glow curves of $BaSO_4$:Eu-Teflon pellets irradiated with 1 kGy (^{60}Co).

The response reproducibility of TL response of the $BaSO_4$:Eu samples was determined after an irradiation of 100 Gy (^{60}Co), and the results are shown in Table 1. It was determined as the percentual coefficient of variation (CV%). The maximum standard deviation was 9.6%, showing an appropriate reproducibility for the tested samples for high-dose dosimetry.

Table 1 – TL response reproducibility as CV_{max} (%) of $BaSO_4$:Eu Teflon pellets.

Eu concentration of BaSO4 samples (%)	*Reproducibility (%)*
0.05	7.8
0.1	8.6
0.2	9.6
1.0	9.1

The TL dose-response curves were also obtained for all samples, and they are shown in Figure 2. All curves present a linear behaviour in the interval 10 Gy– 10 kGy, indicating their usefulness in this dose interval.

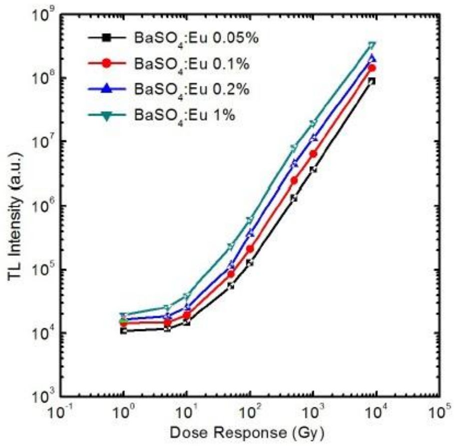

Figure 2: Dose-response curves of $BaSO_4$:Eu-Teflon pellets for ^{60}Co radiation.

Conclusions

All $BaSO_4$:Eu samples are suitable for high-dose dosimetry using the TL and OSL techniques. The $BaSO_4$:Eu (0.05% of Eu) presented the highest radiation sensitivity in relation to samples doped with the other Eu concentrations.

Acknowledgments

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