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Alpha particle radiation detection with LiF:Mg,Cu,P TL detectors using the TSEE technique

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Abstract

LiF:Mg,Cu,P sintered pellets were tested in relation to their exoemissive properties, to verify the possibility of their use for alpha radiation detection. The main dosimetric characteristics as the main glow peak occurring at about 207°C when irradiated with ^{241}Am sources, a linear TSEE response as a function of irradiation time and flux emission, and its suitable reproducibility show their usefulness for alpha radiation detection. © 1999 Elsevier Science Ltd. All rights reserved.

Keywords: TSEE; LiF: Mg, Cu, P detector; TL detectors; Alpha radiation

1. Introduction

The dosimetry of weakly penetrating radiations, such as alpha and beta particles and low energy X-rays, has led to the development of new materials and techniques that present superficial interactions, as happens in the case of exoelectron emission. Thermally stimulated exoelectron emission (TSEE) has received considerable attention in recent years because it is being used to measure short range particles due to the shallow surface within which exoelectrons originate, without loss of sensitivity. The escape depth of exoelectrons is less than 100 nm (Akselrod et al., 1994; Burkhardt et al., 1996; Gammage et al., 1996; Uchrin, 1991).

The TSEE consists of low energy electrons that are emitted from the surface of many insulating solids at temperatures below those at which thermionic emission occurs, following mechanical deformation, physical phase changes, chemical reactions, or exposure of the surface to ionizing radiation (Spurny, 1985). The physical properties of TSEE are related to those of thermoluminescence. Due to an exposure to ionizing radiation, electron traps in the energy band gap of an insulator are occupied. Upon thermal stimulation, these electrons are released from the traps. If their energy exceeds the electron affinity, they will be able to leave the surface of the insulator or the crystal (Ilie and Wernli, 1990; Durham et al., 1991). The emitted electrons are called exoelectrons and a glow curve shows the yield of this emission as a function of the temperature.

Usually the exoelectrons are measured using particle counters, such as windowless Geiger–Müller detectors, ionization chambers or proportional counters. In all devices, the samples are linearly heated up to a specified temperature.

In this work, the properties of sintered pellets of LiF:Mg,Cu,P were investigated using the TSEE technique, to verify their usefulness for alpha radiation detection. LiF:Mg,Cu,P samples have been of considerable interest over the past years in radiation dosimetry, due to their tissue equivalence and high sensitivity (Christensen, 1993; Yuen et al., 1993; Bilski et al., 1996).

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Table 1
Characteristics of the alpha secondary standard sources (^{241}Am) from the Nuclear Metrology Laboratory (IPEN), Brazil

Radionuclide (identification)	Emission flux (s^{-1})
E-11	3.5
E-10	55.3
E-40	102
E-31	506
E-37	1050
E-05	2328
E-34	3601
E-35	6292
E-12	11100
E-25	48500
E-23	82000

2. Materials and methods

LiF:Mg,Cu,P sintered pellets, 4.5 mm in diameter and 0.8 mm in thickness, named GR-200 from China Scientific Instruments Materials, Beijing, were tested in this work.

The samples were subjected to alpha radiation (^{241}Am) from a secondary standard system produced and calibrated at the Nuclear Metrology Laboratory of IPEN, in the range from 3.5 to 8.2×10^4 s^{-1} of emission flux and to another secondary standard system of ^{239}Pu, ^{241}Am and ^{244}Cm sources produced and calibrated at the Laboratoire de Métrologie des Rayonnements Ionisants (LMRI, France). Specifications of these alpha sources are shown in Tables 1 and 2. The irradiation distance was fixed (1.0 mm), according to international regulations (IAEA, 1970). Prior to each irradiation, the samples were thermally treated at 240°C for 10 min.

The readout of the samples was made using a 2π windowless proportional counter, with hemispherical volume, and using P-10 gas flow (10% methane + 90% argon), developed at IPEN (Rocha, 1997), and an operating high voltage of 2.0 kV. The anode is a 50 μm diameter gold wire and is supported by Teflon (PTFE – polytetrafluoro ethylene) insulators that provide connection to the high voltage.

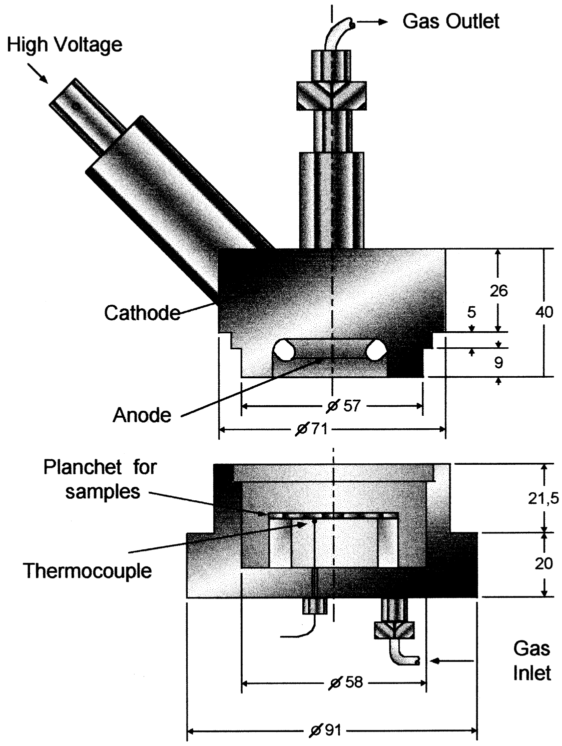

Fig. 1. Diagram of the proportional detector of the TSEE system developed at IPEN (Rocha, 1997). Dimensions in mm.

The diagram of the proportional counter is shown in Fig. 1. The samples were inserted into the active volume of the counter and they were fixed on a heater plate (Monel); heating was linear at a rate of 5.0°C/s. The temperature control for this linear heating was carried out by a temperature programmer TP-2000 (Theall Engineering, USA) that provides rates between 0.1 and 5.0°C/s, from room temperature up to 400°C. The glow curves were recorded in a multichannel scaler (EG and G – Ortec ACE-MCS SN 363 plug-in card).

Table 2
Characteristics of the alpha secondary standard sources from the Laboratoire de Métrologie des Rayonnements Ionisants, France

Radionuclide (identification)	Half-life $T_{1/2}$ (years)	Energy (keV)	Intensity (%)	Emission flux (s^{-1})
^{239}Pu (1617)	$(2.411 \pm 0.003) \times 10^4$	5105.1	11.7	2110
		5143.1	15.1	
		5155.8	73.0	
^{241}Am (1396)	432.7 ± 0.5	5388.0	1.4	1773
		5442.9	12.8	
		5485.6	85.2	
^{244}Cm (1636)	18.1 ± 0.1	5762.70	23.6	1700
		5804.82	76.4	

3. Results and discussion

3.1. Glow curve

Fig. 2 shows the TSEE glow curve for a LiF:Mg,Cu,P sintered pellet irradiated with an ^{241}Am source and an emission flux of 3601 s^{-1} for ten minutes. The TSEE glow curve exhibits various peaks between 50 and 300°C and the main glow peak appears at about 207°C, comparable with those of the TL corresponding glow curve (Holzapfel and Lesz, 1988; Srivastava et al., 1996).

3.2. Reproducibility

The reproducibility of the TSEE response of the LiF:Mg,Cu,P sintered pellets was obtained measuring them ten times after repeated procedures of a standard annealing and an irradiation with an ^{241}Am source of 3601 s^{-1} of emission flux. The TSEE response spread of each pellet, after ten readout cycles, was less than 8.0%. Similar results were obtained by Holzapfel and Lesz (1988) who tested this same material and found a standard deviation of 5.0%, and Borg (1996) who used BeO thin films deposited on circular graphite substrates and after repetitive experiments achieved 6.0–7.0% for the standard deviation of their measurements using a commercial TSEE counting system (ENDOS – TSEE/OSEE counting system type ENDOVA-50, Germany).

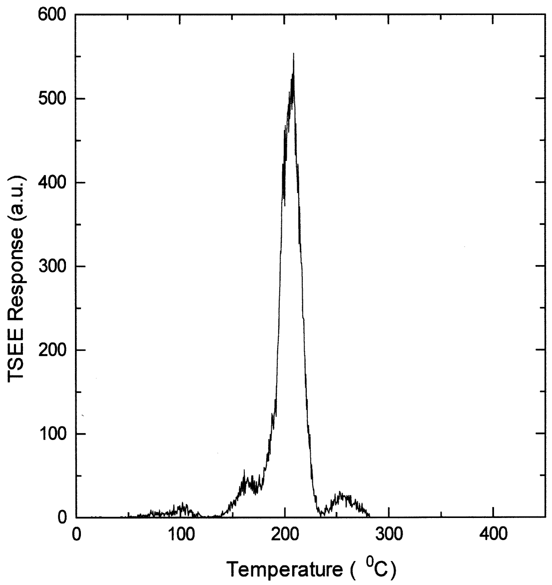

Fig. 2. Typical TSEE glow curve of a LiF:Mg,Cu,P sintered pellet irradiated with alpha radiation source (^{241}Am, 3601 s^{-1}). a.u.: arbitrary units.

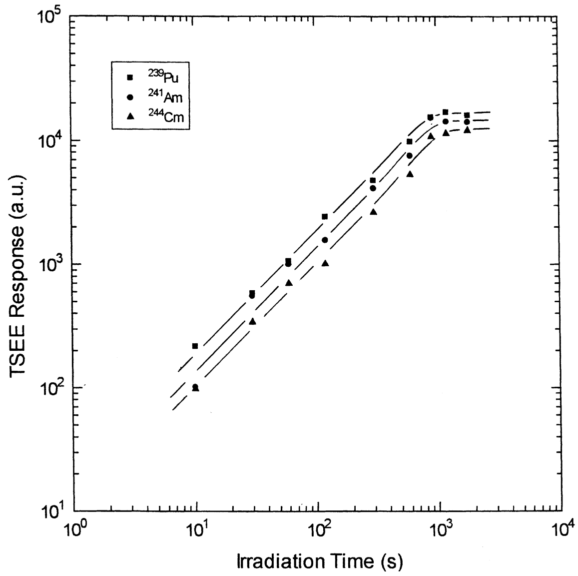

Fig. 3. TSEE response of LiF:Mg,Cu,P sintered pellets as a function of irradiation time (alpha radiation sources). a.u.: arbitrary units.

3.3. Calibration curves

The TSEE response of the LiF:Mg,Cu,P sintered pellets as a function of irradiation time was measured using alpha radiation sources of ^{239}Pu, ^{241}Am and ^{244}Cm; linear responses were obtained up to 900 s of irradiation time. Data are shown in Fig. 3. Measurements errors were always lower than 5.0%.

To verify the response linearity as a function of different values of emission flux from the ^{241}Am sources secondary standard system in the range from 3.5 to 8.2×10^4 s^{-1}, LiF:Mg,Cu,P sintered pellets were subjected, one by one, to the alpha radiation during a time interval of 10 min. The correction factor for the pellet sensibility was determined taking the ratio between the emission flux (3601 s^{-1}) and the mean value of the TSEE response that was obtained in the reproducibility test for each pellet. Fig. 4 shows the obtained results. It can be seen that the TSEE response presents a linear region with the increase of the emission flux and, from 1×10^4 s^{-1}, a tendency to saturation.

4. Conclusion

The results obtained on the main dosimetric characteristics as reproducibility, adequate glow peak temperature and calibration curves of the LiF:Mg,Cu,P sintered pellets indicate that they can be useful for alpha radiation detection using the TSEE technique.

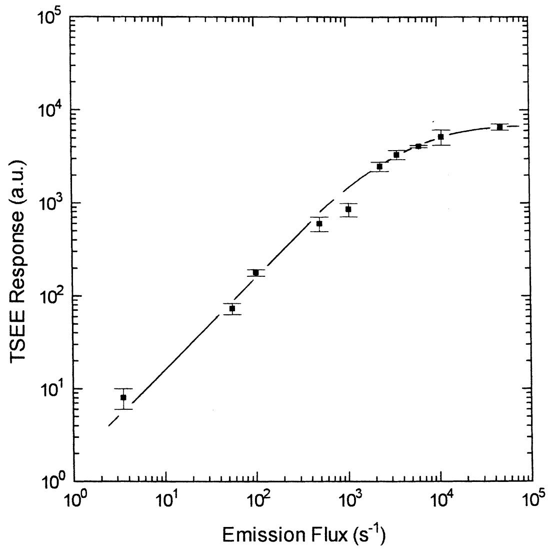

Fig. 4. TSEE response of LiF:Mg,Cu,P sintered pellets irradiated with alpha radiation sources of ^{241}Am (different activities). a.u.: arbitrary units.

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