

CALCIUM SULPHATE SINTERED PELLETS FOR AREA MONITORING OF AN ELECTRON ACCELERATOR USING THE TSEE TECHNIQUE

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Abstract — A thermally stimulated exoelectron emission (TSEE) measuring system developed and constructed at IPEN was used to verify the feasibility of the use of sintered pellets made of pure calcium sulphate (CaSO_4) or CaSO_4 with a 10% graphite content, for area monitoring of an electron accelerator with variable energy. Its counting system consists of a 2π windowless gas flow proportional counter, and the heating system is formed by a temperature programmer that provides linear heating of the samples. The dosimetric characteristics of the samples, such as TSEE glow curve, response reproducibility, calibration curves and energy dependence were studied using the secondary standard system of beta sources from the Calibration Laboratory of IPEN. Measurements of the TSEE response as a function of the absorbed dose were taken, placing these samples in different positions in the accelerator's irradiation room. The obtained results show the usefulness of these materials for area monitoring.

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 is the case with the thermally stimulated exoelectron emission (TSEE) technique^(1–5).

In this work, the properties of sintered pellets made of pure calcium sulphate or CaSO_4 with a 10% graphite content were investigated using the TSEE technique, to verify their usefulness for area monitoring of an electron accelerator. Results on glow curves, response reproducibility, calibration curves and energy dependence are presented.

MATERIALS AND METHODS

Powdered CaSO_4 crystals and chemically pure graphite powder were used to produce sintered pellets of either pure CaSO_4 or CaSO_4 with a 10% graphite content (6.0 mm diameter and 0.8 mm thickness). The dosimetric characteristics of the sintered pellets, i.e. TSEE glow curve, reproducibility, etc., were determined using the secondary standard system of beta sources from the Calibration Laboratory of IPEN. The set-up consists of a source stand, a control unit with timer and interchangeable beta sources of ^{90}Sr - ^{90}Y , ^{204}Tl and ^{147}Pm . Measurements of the TSEE response as a function of the absorbed dose were carried out using an electron accelerator from Radiation Dynamics Inc., model Dynamitron number E00-10210, of IPEN. The beam energy can be varied from 0.5 to 1.5 MeV, the current from 0.3 to 25 mA and the scanner width from 60 to 112 cm. Prior to each irradiation, the samples were thermally treated at 300°C for 15 min. The readout of the samples was made in a 2π windowless proportional counter with

hemispherical volume and with P-10 gas flow (10% methane + 90% argon), developed at IPEN⁽⁵⁾. The samples were read out, fixed on a heater plate using linear heating at a rate of $5.0^\circ\text{C}\cdot\text{s}^{-1}$. The temperature control of this heating is carried out by a temperature programmer TP-2000 (Theall Engineering Company), which provides rates between 0.1 and $5.0^\circ\text{C}\cdot\text{s}^{-1}$, from room temperature to 400°C. The glow curves were recorded in a multichannel scaler (EG&G-Ortec ACE-MCS SN 363 plug-in card).

RESULTS

Glow curve

Figure 1 shows the TSEE glow curve for a sintered pellet made of CaSO_4 with a 10% graphite content irradiated with 10 mGy of beta radiation (^{90}Sr - ^{90}Y). A similar glow curve was obtained for the pellet of pure CaSO_4 . The main glow peak appears at about 120°C.

Reproducibility

The reproducibility of the TSEE response of the CaSO_4 sintered pellets was obtained measuring them 10 times after repeated standard annealing and irradiation procedures. The standard deviation after ten readout cycles was lower than 5.0% for both materials.

Calibration curves

The TSEE response of both kinds of material as a function of the absorbed dose was obtained, placing the samples directly in the electron beams, in the centre of the displacement car, as shown in Figure 2, in the range of 0.45 to 10.0 kGy. The beam energy was kept constant at 0.6 MeV; only the current intensity was varied. The

results obtained for $\text{CaSO}_4 + 10\% \text{ C}$ pellets are shown in Figure 3. The response of the pure CaSO_4 sintered pellets in this dose range was in the saturation region and is therefore not shown. It can be seen that for $\text{CaSO}_4 + 10\% \text{ C}$ the TSEE response presents a linear region up to about 1.0 kGy, followed by a saturation tendency. The standard deviation values were not greater than 3.0% for dose measurements with both kinds of materials.

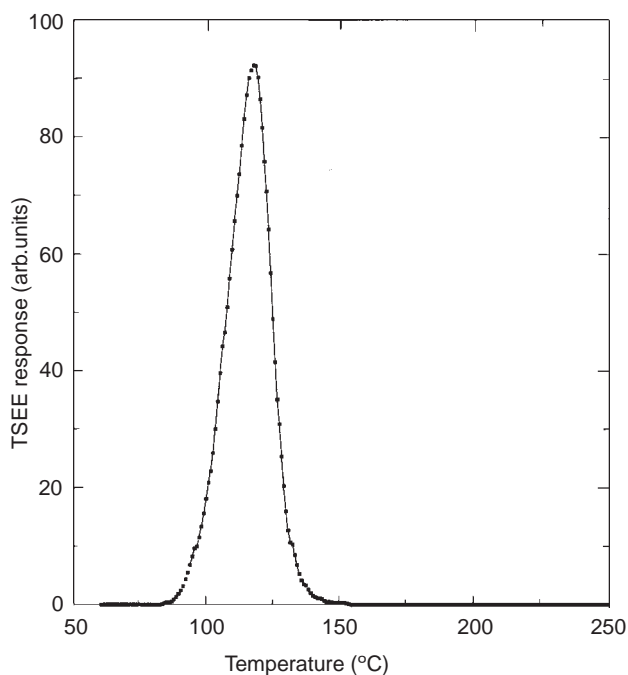


Figure 1. Typical TSEE glow curve of a sintered pellet made of CaSO_4 with 10% of graphite content irradiated with 10 mGy of ^{90}Sr - ^{90}Y .

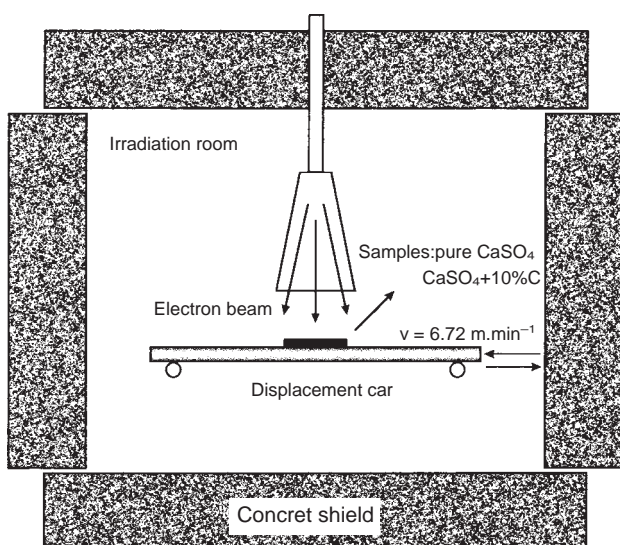


Figure 2. Set-up of the Dynamitron electron accelerator of IPEN.

Area monitoring

To monitor the irradiation room of the electron accelerator, the samples of pure CaSO_4 and $\text{CaSO}_4 + 10\% \text{ C}$ were placed in three different positions on the wall, and the absorbed dose was varied, increasing the number of displacements of the irradiation car. The current intensity (0.3 mA) and the beam energy (0.6 MeV) were kept constant. The irradiation distances were 1.3, 1.9 and 4.1 m from the electron beam centre. The standard deviation values, associated with the measurements, were not greater than 3.5% in either case. Figure 4 shows the TSEE response as a function of the distance for $\text{CaSO}_4 + 10\% \text{ C}$ sintered pellets. The absorbed doses were varied from 0.45 kGy (1 displacement) to 7.2 kGy (16 displacements). A rapid decrease in the TSEE response with the increase of the irradiation distances can be observed. The absorbed doses for one of the irradiation distances (1.3 m) and for different numbers of displacements of the irradiation car were determined using the linear region of the calibration curve shown in Figure 3, in the case of $\text{CaSO}_4 + 10\% \text{ C}$ sintered pellets.

Energy dependence

The TSEE response of the CaSO_4 sintered pellets was also verified varying the radiation energy between 0.6 and 1.5 MeV. For this case the current intensity (0.3 mA) and the number of car displacements (1) were kept constant. The obtained results are shown in Table 1. The uncertainties were always less than 5.0% for both materials. It can be observed that for pure CaSO_4 sintered pellets the energy dependence is high

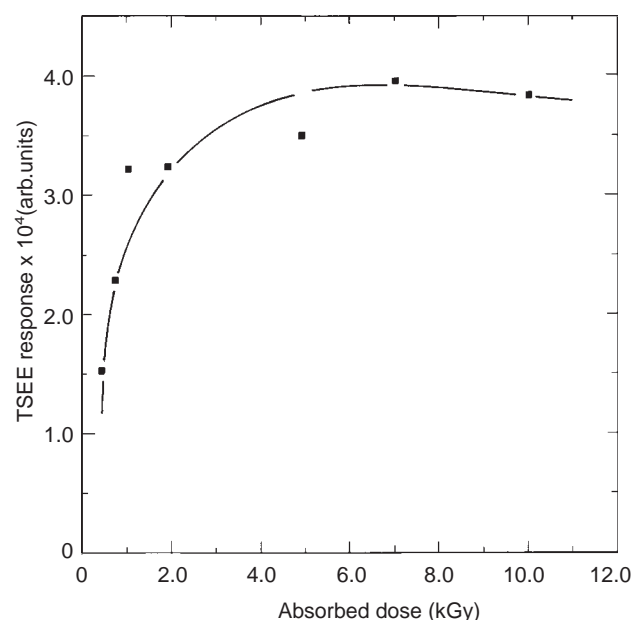


Figure 3. Calibration curve of sintered pellets made of CaSO_4 with 10% of graphite content (■), irradiated at the electron accelerator.

(47.0%), but in the case of CaSO₄ + 10% of graphite the TSEE response is almost independent of the energy (7.0%). According to Borg⁽²⁾, the energy dependence of BeO, one of the best materials for exoelectron dosimetry (for its tissue equivalence), for beta rays with maximum energies in the range 67 keV to 2.27 MeV is also high (30.0%). The even higher energy dependence of CaSO₄

in relation to BeO is probably due to the difference in their effective atomic number.

CONCLUSIONS

The results obtained show the feasibility of using sintered pellets made of CaSO₄ with a 10% graphite content for the dosimetry of the electron beam, as well as for area monitoring of an accelerator facility, using the thermally stimulated exoelectron emission measuring system developed at IPEN. The significant energy dependence of the pure CaSO₄ pellets does not recommend them for radiation dosimetry using the thermally stimulated exoelectron emission technique.

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Table 1. Energy dependence of sintered pellets made of pure CaSO₄ and CaSO₄ with 10% of graphite content for electron beams from the Dynamitron accelerator.

Energy (MeV)	TSEE Relative Response × 10 ⁴ (arb. units)	
	CaSO ₄	CaSO ₄ + 10% C
0.6	4.952	3.680
0.8	4.321	3.663
1.0	3.370	3.933
1.5	3.360	3.900

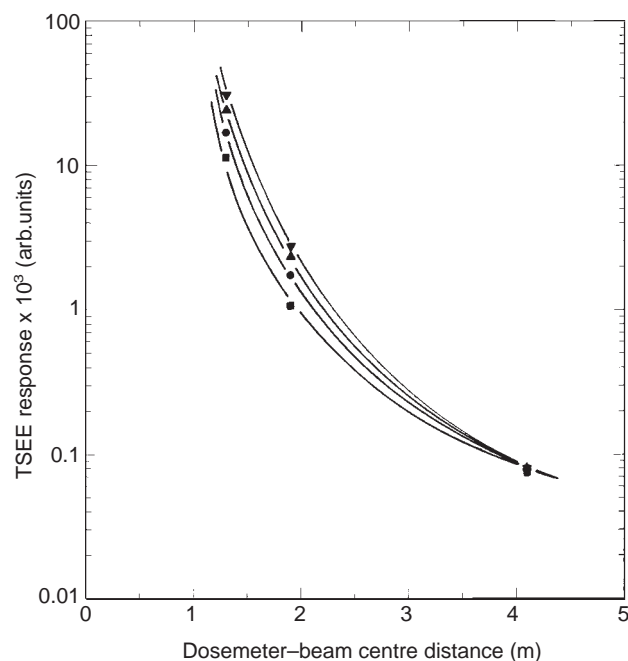


Figure 4. TSEE response of sintered pellets made of CaSO₄ with 10% content of graphite as a function of different positions of irradiation. Displacements: (■) 1, (●) 4, (▲) 8, (▼) 16.

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