A FEASIBILITY STUDY FOR DOSIMETRY WITH THERMALLY STIMULATED EXO-ELECTRON EMISSION (TSEE) IN BeO

C. Wernli, R. Zuk
EIR, Swiss Federal Institute for Reactor Research
Health Physics Division SU/81
CH-5303 Würenlingen / Switzerland

INTRODUCTION

The objective of this work was to determine the feasibility of thermally stimulated exoelectron emission (TSEE) from BeO thin film detectors as a method for low energy beta dosimetry. The research included the summarization of related papers and experimental work to verify the claimed characteristics of these detectors.

Experiments were performed to determine:

a) necessity for Geiger counter cooling
b) the effect of counter gas flow-rate variations
c) correct anode voltage for exoelectron measurement
d) annealing temperatures required for maximum sensitivity
e) fading of signal and activation of the detectors by fluorescent tube lighting
f) response of unirradiated detectors (noise)
g) lower detection limit
h) reproducibility
i) fading and activation at 50°C
j) linearity of detector response to radiation dose
k) sensitivity to beta and gamma radiations

DESCRIPTION OF THE MEASUREMENT TECHNIQUES

The detectors used here were developed at the Battelle Institute, Frankfurt and the University of Giessen, both of the Federal Republic of Germany (Kottler and Lerch, 1980). The preparation of the detectors consists of the deposition of a thin Be film on a graphite disc, followed by oxidation in a wet nitrogen atmosphere at 1300°C.

The exoelectron reader was a DIGITEC (Lesz and Holzapfel 1985) methane gas-flow, mono-point Geiger counter with a built-in heater. Readouts averaged 7 minutes per detector and a calibration cycle required 5 minutes.

Thorough flushing of air from the Geiger chamber was very important. Air contamination shortened the Geiger plateau length, changed the counting characteristics and increased the chance of sparking damage to the anode.

On start-up, with the ^{14}C calibration source and guarded anode, the Geiger plateau was 400-500 V in length and had a slope of less than 2 %/100 V. The plateau did slightly shorten and the slope slightly increase after several heating cycles.

The anode voltage for exoelectron readouts was chosen to be 3400 V (with 99.995 % methane and a guarded anode). This voltage gave a well defined Geiger peak in the pulse height distribution (PHD) and did not cause counter saturation at higher pulse rates. This voltage was 200 V higher than that used for the ^{14}C calibrations. This discrepancy is explained by the fact that the Geiger plateau for ^{14}C is not transferable to exoelectrons.

The discriminator lower level cutoff voltage was set to equal the position of the minimum between noise and Geiger peak in the pulse height distribution, rather than the electronic noise level (0.2 V). This choice of threshold eliminated less than 10 % of discernable counts, was very easy to determine and was stable. Counting rates resulting from 4,3 mGy doses (less than 2000 s^{-1}) did not shift the PHD enough to warrant changing the threshold level.

The counting cycle was made almost completely automatic by interfacing with the heater control. Some of the detectors had their second emission peak extending to 520°C. However, since the noise counts increased significantly at the higher temperatures, 500°C was used as the upper bound on peak 2.

RESULTS AND DISCUSSION

Cooling of the counter was found to be necessary after it was noticed that the calibration source pulse rates were varying as a function of the number of heating cycles that had been performed. Experimental heating of the counter increased pulse rates. This effect was probably due to an increase in the gas amplification factor caused by methane expansion as it passed by the heater assembly.

Gas flow-rate did not affect the ^{14}C calibration source pulse rate, with an anode voltage of 3100 V. This was in agreement with the DIGITEC counter manual. However, Geiger plateau length was shortened by as much as 100 V with maximum gas flow-rates. The effect of gas flow-rates on exoelectron counting characteristics was not determined.

PHD's from TSEE readouts did not have well defined Geiger peaks when readouts were performed with an anode voltage chosen with the ^{14}C calibration source. The incorrect anode voltage resulted in an apparent poor detector sensitivity and stability. An attempt was made to define the exoelectron Geiger plateau by plotting total counts (at constant dose) vs anode voltage. The Geiger plateau was not obvious enough to determine an anode working voltage. Instead, an exoelectron working voltage was found by observing the TSEE PHD's as anode voltage was increased. The optimal 3400 V (with 99.995 % methane and guarded anode) was chosen because it was high enough to provide a well defined Geiger peak and not so high that it caused counter saturation at higher count rates.

For complete emptying of the electron traps, annealing by heating at 2°/s, to 550°C, was found to be satisfactory. This compares to a final temperature of 450°C (reading Peak 1 only) by Kottler and Lerch (1980) and 580°C by Lesz et al (1985). Higher anneal temperatures did not reduce the residual counts measured when a second readout was performed immediately after the anneal.

Exposure to fluorescent tube light at a distance of 30 cm caused both TSEE signal fading and activation. Fading in Peak 2 was negligible but Peak 1 counts had decreased by 15-40 % after 30 minutes. Activation occured in Peak 1 with an apparent dose of 1-7 μGy/hour and in Peak 2 at 13-23 μGy/hour. These effects would be decreased by about a factor of 10 in a room with ceiling mounted lights.

Unirradiated detectors had a noise level of 5-12 counts in Peak 1 and 50-130 counts in Peak 2 (guarded anode), independent of detector sensitivity variations. Sensitivities were 7-14 exoelectrons/μGy · cm^2 in Peak 1 and 20-40 exoelectrons/ μGy · cm^2 in Peak 2. These sensitivities compare with total sensitivities of 30-50 exoelectrons/μGy · cm^2, reported by Kottler and Lerch (1980).

Requiring that the signal-to-noise ratio be at least 3, the minimum detectable dose was 5-10 μGy in Peak 1 (detector area = 0.4 cm^2).

The uncovered detector sensitivities were very similar for beta and gamma radiation from Cs-137, Am-241, Pm-147, Tl-204 and Sr/Y-90 radionuclides, as shown in Table 1.

TABLE 1 Sensitivities to Gamma and Beta Radiations for the uncovered detector (for ^{137}Cs a perspex buildup cap was used): The sensitivities were calculated for constant dose at a tissue depth, d=0. Estimated uncertainty in parentheses.

ISOTOPE	PHOTON ENERGY (keV)	AVERAGE β-ENERGY (keV)	SENSITIVITY RELATIVE TO CS-137 PEAK 1	PEAK 2
^{137}Cs	662	-	1.0 (6%)	1.0 (10%)
^{241}Am*)	59	-	1.5 (25%)	1.7 (26%)
^{147}Pm	-	62	1.1 (12%)	1.1 (14%)
^{204}Tl	-	244	1.15 (8%)	1.15 (8%)
$^{90}Sr+^{90}Y$	-	570	1.1 (12%)	1.2 (11%)

*) The Am-241 source dose rate was not known accurately

Reproducibility averaged 95 % and was never worse than 93 % for a series of 12 consecutive readouts on each of four detectors (4.3 mGy doses).

A temperature of 50°C did not cause rapid fading or activation in the detectors. Measurements over a period of 17 days indicate a possible 5-10 % fading per 10 days.

Linearity of dose response was verified in the range of 5 - 570 µGy. This is in agreement with all reports to date.

CONCLUSION

Experiments performed for this report were generally in agreement with available literature. Exoelectrons and ^{14}C betas were found to have very different counting characteristics, with no Geiger plateau to be found for exoelectrons. Fluorescent lighting of the detectors caused significant fading and activation but exposures while performing a readout were acceptable. Storage in darkness was necessary. Total sensitivities were 34-50 exoelectrons/µGy · cm^2, giving lower detection limits of 5-10 µGy in Peak 1 and 20-30 µGy in Peak 2. Measurements had better than 94 % reproducibility with consecutive 4,3 mGy doses, however, sensitivity varied from week to week. Linearity of detector response to dose was shown within a range of 5 to 750 µGy. Counter cooling was necessary and gas flow-rates did not affect the calibration source count rates. A final anneal temperature of 550°C was found to be sufficient to restore maximum detector sensitivity. The uncovered detectors showed similar sensitivity to gamma and beta radiation from Cs-137, Am-241, Pm-147, Tl-204 and Sr/Y-90.

The completed experiments indicate that BeO TSEE dosimetry can be useful for measuring low energy beta or mixed field radiations. The stability of detectors and counting technique needs to be investigated further. BeO TSEE dosimetry may still be considered feasible but more testing should be performed before practical application of the technique.

REFERENCES

Kottler, W. and Lerch, D. "Evaporated BeO Films for TSEE Dosimetry" Nucl. Instrum. Methods, 175, 1980, pp. 101-103

Lesz, J. and Holzapfel, G. "Electronic Characteristics of a Mono-Point TSEE/OSEE Geiger Counter" Proc. 8th Intern. Symp. on Exoelectron Emission and Applications, Osaka. Jap. Journ. Appl. Phys., 24(24-4), 1985, pp. 266-269