TSEE DOSIMETER FOR GAMMA-RAYS AND FAST NEUTRONS USING CERAMIC BeO

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The dosimeter applying thermally stimulated exoelectron emission (TSEE) has been expected since Kramer[1] reported the linear relation between dose and TSEE. Its merits are high sensitivity, small size, and sensitivity only on surface. However it has not been used practically, since TSEE depends on the content of impurity, method of sample preparation, and surface condition.

Several different materials such as LiF, BeO, $CaSO_4$, CaF_2, $Li_2B_4O_7$ were examined by measuring TSEE glow curves in our laboratory. Of them ceramic BeO with special treatment was found to have high sensitivity and sufficient reproducibility when used as a dosimeter. In this paper are described method of sample preparation, TSEE measuring system, and characteristics of the dosimeter exposed to γ-rays and fast neutrons.

EXPERIMENTALS

Ceramic BeO called "Beryllia K-99" manufactured by "NGK Insulators Ltd"-Japan is 99% purity and in the disk form of 12 mm in diameter and 0.5 mm thick. Na^+ ion doping was made first by heating the disk at 1,400°C for 2 hours, cooling, then immersing in 1 M Na_2SO_4 solution, drying until Na_2SO_4 crystallized on the surface and finally heating at 900°C for 2 hours. The disk was placed in a recess, 12.5 mm in diameter and 0.5 mm deep, in a graphite holder as a dosimeter, whose outer dimensions were 15 mm diameter by 1 mm thickness. Before use, the dosimeter was annealed at 550°C for over 30 minutes to eliminate the effects of background radiation and mechanical excitation. Heatings were all done in air by an electric furnace.

For fast neutron measurement, a difference method[2] was used. Ten dosimeters of same sensitivity were selected and put in an aluminium holder. Five of them were each covered with a 2 mm thick polyethylene disk as a recoil proton radiator and another five each with a 2 mm thick polytetrafluoroethylene (Teflon) disk as a reference.

TSEE measurement of the dosimeter was made with a windowless gas flow G-M counter. The counting gas was Q-gas consisting of 99% helium and 1% isobutane. During the measurement, the dosimeter was heated up linearly at heating rate 1.5°C/sec from 100°C to 500°C. The pulse rate of TSEE from the dosimeter was recorded on an X-Y recorder and also on a punched tape through a variable time-base counter every 5 seconds.

Responses of the dosimeter to γ-ray exposure and fast neutron dose were obtained by using radiation sources of 20 mCi of ^{60}Co, 1 Ci of ^{239}Pu-Be and 1 Ci of ^{241}Am-Be. The exposure to ^{60}Co source was measured by a Victoreen R-meter calibrated by "Electrotechnical Laboratory"-Japan. Total neutron fluence rate of ^{241}Am-Be source was subjected to international neutron source intercomparison at LRL-Berkeley in 1970. The fast neutron dose was calculated from fluence based on kerma factor of muscle[3)] for soft tissue. The average neutron energy of the sources was assumed to be 4.5 MeV.

RESULTS AND DISCUSSION

Ceramic BeO without the above treatment shows low sensitivity to radiations, poorly reproducible glow curves, and spurious TSEE bursts of hundreds counts. In some ceramic BeO disks, successive measurements result in a glow peak at heater temperature of 280°C, which grows large with the number of measurements up to several. This may be related to the properties of ceramic BeO; this is, high specific resistance causing ion accumulation on the surface during measurement, or pyro-electricity.

Figure 1 shows a TSEE glow curve of ceramic BeO dosimeter with the above treatment for γ-ray irradiation, together with the background curve. The glow curve has two peaks, a higher one at 365°C and a lower one at 420°C. The sensitivity expressed as the number of exoelectrons counted per unit exposure is improved up to 1.2×10^4

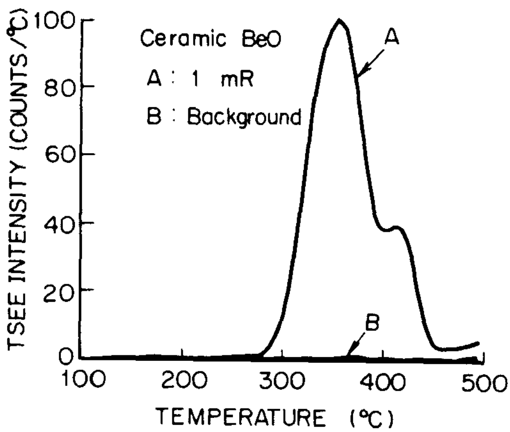

Fig. 1 TSEE glow curve of ceramic BeO dosimeter irradiated 1 mR of ^{60}Co γ-rays, together with background curve. Temperature is measured under a graphite sample holder.

counts/mR. The scattering in sensitivity of ten dosimeters chosen from the twenty for a 10 mR exposure is standard deviation ± 3.7%, while the reproducibility of a dosimeter exposed to 1 mR in five measurements is ± 2.0%. Fading of the radiation induced signals is not observed after keeping at 150°C for 1 hour. Sensitivity of some dosimeters gradually decreases with time in leaving them in the atmosphere of the room. By re-treatment, their sensitivity is recovered.

The TSEE response versus exposure is shown in Fig. 2.

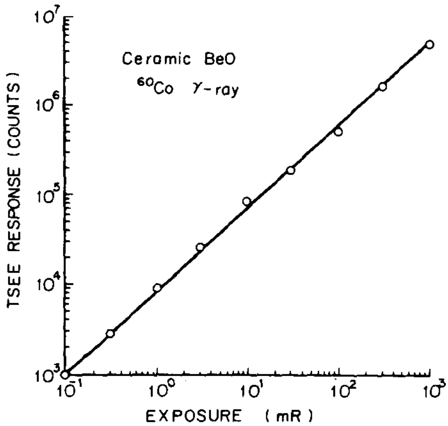

Fig. 2 TSEE response versus exposure.

It is linear on a log scale over the measured range from 100 μR to 1 R. In the figure, response R_g (counts) of the dosimeter for exposure X (mR) can be expressed by $R_g = 8.96 \times 10^3 \times X^{0.93}$. The lower detectable limit of exposure for the dosimeter is well below 10 μR, assuming that the significant difference between the net count of TSEE and the background count of the counter is more than three times the standard deviation.

The glow curves covered with polyethylene and Teflon disk respectively, irradiated by fast neutrons are similar in shape. But the former shows a higher peak due to the recoil proton component. Neutron response of the dosimeter is obtained by subtracting the reading with Teflon-covering from that with polyethylene-covering. The response of a group of the ten dosimeters previously selected and irradiated to a given dose is given by first expressing the individual mR equivalent calibrated by ^{60}Co γ-rays, then averaging each five dosimeters, and finally taking the difference. The TSEE response versus fast neutron dose is shown in Fig. 3. It is also linear on a log scale over the measured range from 500 μrad to 70 mrad, and the

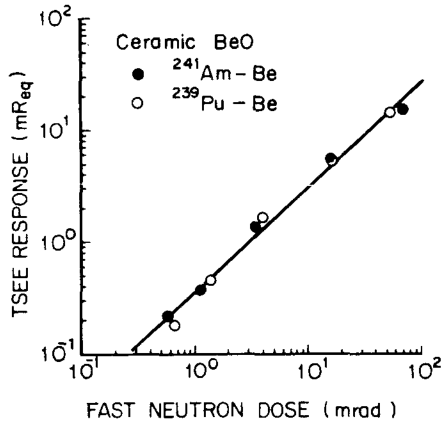

Fig. 3 TSEE response versus fast neutron dose. Response is average value of five pairs of dosimeters, and expressed by mR equivalent of ^{60}Co γ-ray exposure.

results with the two different neutron sources are in agreement. In the figure, TSEE respons R_n (mR_{eq}) of the dosimeter for D_n (mrad) can be expressed by $R_n = 0.37 \times D_n^{0.95}$. In this equation, the response for TSEE from 1 mrad of fast neutron dose is equivalent to that for 0.37 mR of γ-ray exposure. The lower detectable limit of fast neutron dose in a mixed field of γ-rays and fast neutrons is 14 μrad in 10 μR background, and 100 μrad in 1 mR, if the dosimeters are well calibrated and the TSEE response deviates only with statistical error of counting.

As seen above, the ceramic BeO dosimeter has outstanding characteristics such as suitable temperature of glow peaks, high sensitivity, and stability. Efforts are now in progress to develop dosimeters of high reliability in various circumstances, make number of dosimeters having the same characteristics, and attain higher sensitivity to radiation dose.

REFERENCES

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