EFFECT OF GAMMA RADIATION ON THE THERMOELECTRET STATE OF BeO*

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(With 5 text-figures)

I. INTRODUCTION

Beryllium Oxide is already well known as a good dosimetric material due to the relatively high thermally stimulated exoelectron emission (TSEE) and thermoluminescence (TL) outputs of irradiated specimens [1].

Our previous studies on the destruction of the thermoelectret state of BeO, by measuring thermally stimulated depolarization currents (TDC), showed that [2]: a) the TDC spectrum presents two peaks in the temperature range RT-600 C, but only the high temperature peak (~230C) is dected in specimens previously polarized at temperatures higher than ~230C; b) the measured charge of the thermoelectret obtained under usual experimental conditions (see below) is of the order of 10^{-9} Coul/cm^2.

The application of radiation induced conduction and/or polarization effects in high temperature oxides to ionizing radiation dosimetry has already been proposed [3]. In these materials the onset of the ionic conductivity is at higher temperatures relative to the alkali halides making easier the design of apparatus for routine measurements of radiation doses. Moreover, the large applicability of these materials in Electronics, for example BeO chips as heat sinks, has made available in large quantities these oxides.

In this work we describe the effect of gamma radiation on the thermoelectret state of Brush Thermalox 995 Beryllium Oxide, taking into account the possibilities of using this material as a radiation dosimeter by the thermal depolarization current technique.

II. EXPERIMENTAL

The specimens used in this experiment were Brush Thermalox 995 BeO***, in the form of discs of diameter 12.7mm, and thickness 1.57mm.

A description of the TDC measurements is given elsewhere [2].

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*** Manufactured by Brush Beryllim Co., Elmore, Ohio, USA.

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The irradiation facilities consisted of ^{137}Cs and ^{60}Co gamma cells of different intensities. Specimens were irradiated with electrodes on open circuit. Dark current-temperature measurements were obtained during the heating up of the unpolarized specimen. All irradiations were performed at room temperature.

Heat treatments for reuse of irradiated specimens were 600 C/30 min [2, 4].

III. RESULTS

Figure 1, curve a, shows a typical TDC spectrum of BeO; curve b was obtained after exposing the specimen to 1 R of gamma radiation at room temperature. The difference in integrated areas under curves b and a gives a radiation-induced polarizable charge ΔQ. This quantity might, in principle, be a measure of gamma radiation dose. Curve c was obtained during the heating of a specimen exposed to 1 R of gamma radiation after the formation of the thermoelectret state. The curves a, b and c in Fig. 1 were obtained after the same polarizing conditions, and heating cycles.

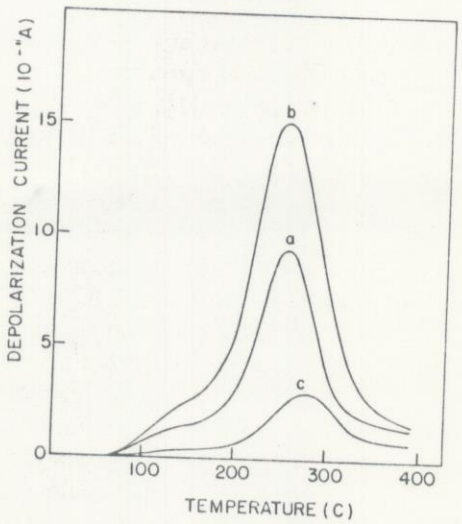

Fig. 1. Thermally Stimulated Depolarization Current spectra of BeO; a) unirradiated specimen, b) and c) specimen exposed to 1 R of ^{60}Co gamma radiations at RT before and after the formation of the thermoelectret state, respectively.

In Figure 2 the dependence of the radiation-induced charge ΔQ on the gamma radiation exposure in the O R – 10^3 R range is shown. A large increase of the induced polarization in the 100 R range and a relatively slow increase for higher radiation exposures are observed.

In Figure 3, some preliminary results in the lower gamma-exposure range are shown. Although more systematic investigations are necessary, the difference in peak amplitudes (or in integrated areas) of TDC spectra of samples exposed to gamma radiation in the mR range is easily detected. However, there is a disadvantage in using this material in Personnel Dosimetry: a large fading in the polarizable charge induced by radiation is

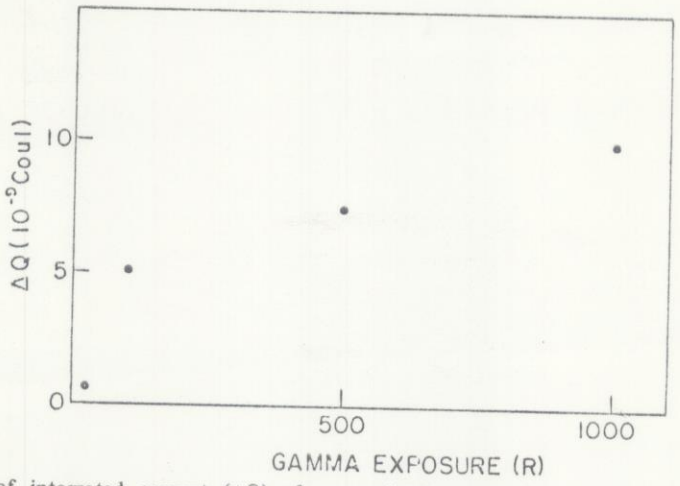

Fig. 2. Values of integrated current (ΔQ) of gamma-irradiated BeO as a function of gamma-ray exposure (OR-10^3R). All readings were corrected for the integrated current due to unirradiated specimen.

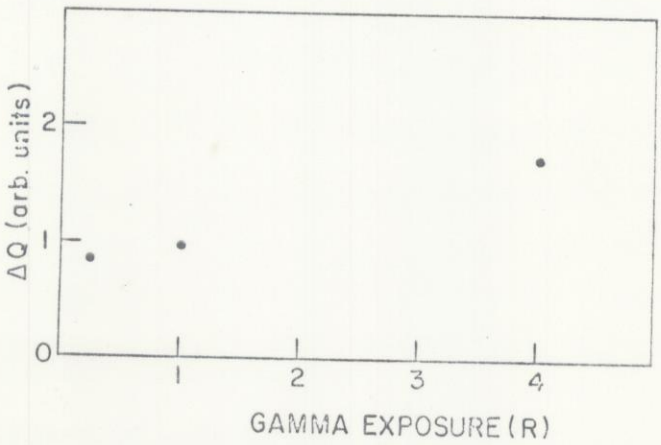

Fig. 3. Values of integrated current (ΔQ) of gamma-irradiated BeO as a function of gamma-ray exposure (mR range). The values were corrected for the integrated current due to unirradiated specimen.

detected. In Figure 4 the decrease in the measured charge ΔQ for different post-irradiation storage times in shown. The half-life of this decrease is of approximately 15h, too small for personnel dosimetric systems.

In Figure 5, several thermal depolarization current spectra are shown. Curves a, b and c were obtained in the same sample exposed to the same gamma radiation dose. An annealing of 600 C/30 min was performed after every experiment in order to erase the radiation-induced defects. Curve d is for a non irradiated sample. The difference in peak temperature in some TDC spectra is due to different heating rates. The observed deviations in peak amplitudes of the spectra of irradiated specimens is found to be higher than fifteen percent.

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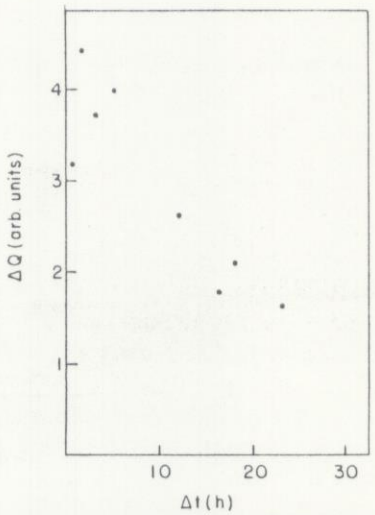

Fig. 4. Fading of the radiation-induced polarization in BeO. Gamma-radiation exposure: 1R.

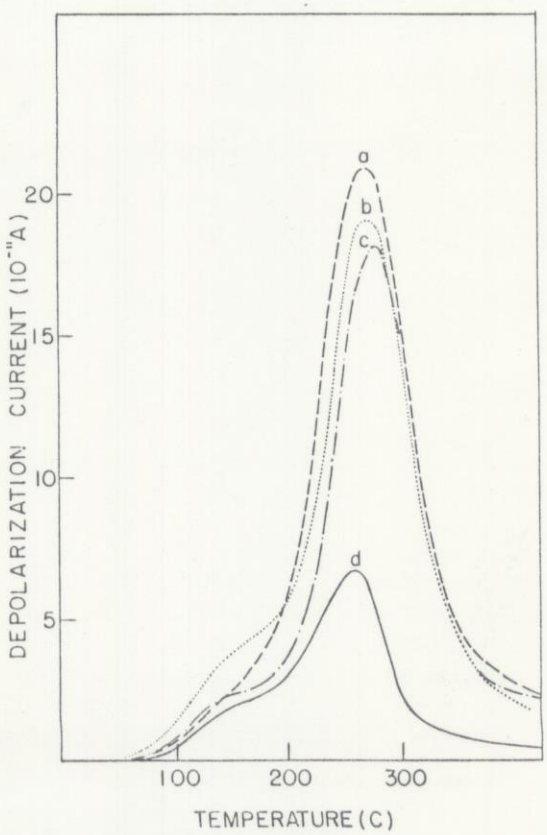

Fig. 5. TDC spectra of BeO. Curves a, b and c for samples exposed to the same gamma-radiation dose; curve d for unirradiated BeO.

In the table I below, a comparison for several materials using different dosimetry techniques is shown. The values for techniques other than TDC were taken from Ref. 3.

TABLE I

Values of relative sensitivity of several dosimetric materials utilizing different following techniques: Radioelectret (RE), Thermally Stimulated Exo-electron Emission (TSEE), Thermoluminescence (TL), Radiation-Induced Thermally Activated Conductivity (RITAC), and Thermally Stimulated Depolarization Currents (TDC). The last figure refers to the present work, while the others were taken from Ref. [3].

Technique	Material	Relative Sensitivity (Coul/R)
RE	–	$10^{-14} - 10^{-15}$
TSEE	BeO	10^{-14}
TL	TLD-200	10^{-12}
RITAC	saphire	10^{-9}
TDC	BeO	7×10^{-10}

Even though the fading of the radiation induced signal is too high and a deviation of more than fifteen percent is measured, we think that improving the experimental conditions, and performing more systematic experimental work will help to get more information on the utilization of BeO as a dosimeter for measuring penetrating radiation.

Experiments are under way in order to get a knowledge of the mechanisms responsible for the enhancement of the amplitudes of the discharge currents in irradiated BeO.

ABSTRACT

The thermoelectret state of Beryllium Oxide (Brush Thermalox 995) ceramics exposed to gamma radiation have been studied by the thermal depolarization current technique. The gamma exposures have been performed either before polarizing the samples or after the formation of the thermoelectret state. It was found no qualitative change in the thermal depolarization spectra of irradiated and unirradiated samples, but there is an enhancement of the induced polarization of pre-irradiated specimens relatively to the unirradiated ones. Moreover, a proportionality is found between gamma radiation exposures and detected charge densities. The possibilities of using BeO as a thermoelectret gamma radiation dosimeter are considered.

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