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Letter to the Editor

INVESTIGATION OF TEFLON ELECTRET DETECTORS FOR BETA DOSIMETRY

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Cylindrical electret ionization-chamber-type dosimeters exposed to beta radiation show a partial decay of their polarization. Different radiation field geometries and wall materials for the outer jacket were tested.

The electret is a solid dielectric bearing a persistent polarization due to a "frozen-in" nonequilibrium distribution of electric charge [1]. If an electret is subjected to ionizing radiations, the charges produced in the atmosphere surrounding them will be attracted to the electret surface, reducing the net surface charge. Therefore the apparent electret charge will decrease with increasing radiation absorbed dose. This is the principle of the electret radiation dosimeter.

A cylindrical electret ionization-chamber-type dosimeter has been studied for X- and gamma-rays [2–4] and for neutrons [5].

Preliminary experiments for beta radiation detection were performed [6]. In the present work the same simple system, similar to a cylindrical ionization chamber (3.5 cm^3 sensitive volume), using Teflon electrets was used. Fig. 1 shows such an electret detector [5].

A metal needle was used to support the cylindrical Teflon electret (E). This needle was connected to the outer conductor (M), allowing the electret polarization to induce an electric field in the cylindrical region between the Teflon and the outer jacket (W). The cap (C) on the extremity of the detector was removed for the measurement of the electret charge. The wall material for the outer jacket was either aluminum or lucite (1 mm thickness). Aluminum walls with five longitudinal openings (0.6×3 mm^2) were also used. The internal surface of the lucite wall was covered with a thin layer of graphite. Experiments were also performed using chambers without the outer wall. In this case, the chamber does not have a well defined sensitive volume.

The Teflon electrets were produced by corona discharge in the air surrounding them. The initial and final charges are measured by induction, using a coaxial-insulated metal chamber connected to a Keithley electrometer 610 C. For this procedure the cap C is removed and the electret E introduced into the induction electrode. Under favorable conditions (namely a complete collection of ions in the chamber) the difference between the initial and final charges was found to be proportional to the absorbed dose D:

$$Q_f - Q_i = KD,$$

where K is a constant independent of the electret charge.

All irradiations were made with the $^{90}Sr + {}^{90}Y$ (1850 MBq) and ^{204}Tl (18.5 MBq) sources with mean energies of 0.8 and 0.24 MeV respectively of the beta secondary

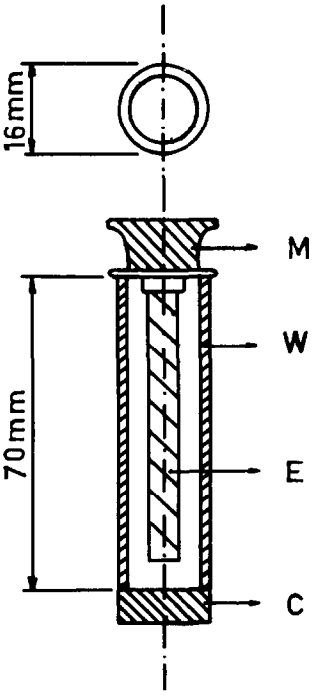

Fig. 1. Cylindrical electret detector: E: Teflon electret, M: outer conductor, W: outer jacket, C: aluminum cap.

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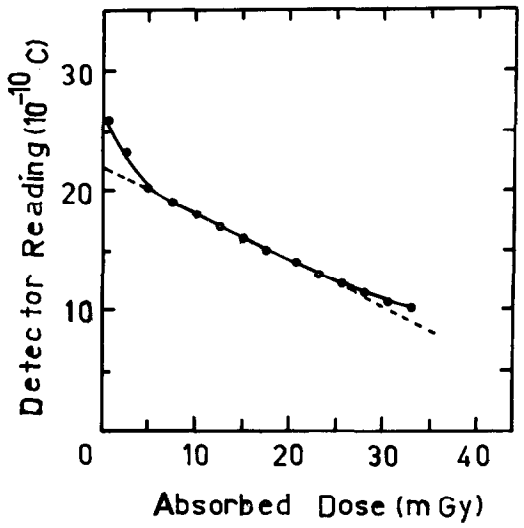

Fig. 2. Response curve to $^{90}Sr + ^{90}Y$ radiation.

standard system of the Calibration Laboratory of São Paulo (IPEN). This system was developed by the Physikalisch-Technische Bundesanstalt (PTB, Germany) and manufactured by Buchler & Co. (Germany). It consists of a source stand, a control unit with timer and different interchangeable sources. Compensation filters of plastic foils provide for field homogeneity within a diameter of 11 cm at the calibration distances. The setup was used in an irradiation room specially designed for this purpose, to avoid any scattered radiation problems. The electret dosimeters were exposed to beta radiation at the calibration distances (between 11 and 30 cm) given in the PTB calibration certificates.

The electret dosimeters were tested with the electret axis parallel and perpendicular to the radiation field. The most important characteristics for beta dosimetry – reusability, sensitivity, absorbed dose response and energy dependence – were investigated in this work.

A typical dose response curve is shown in fig. 2. The electret dosimeter was exposed to successive equal absorbed doses and the remaining charge on the electret was measured after each irradiation. In this way the useful charge range was determined, where the detector readings present a linear response as a function of absorbed dose. The detector was exposed in this case to the $^{90}Sr + ^{90}Y$ radiation source. Fig. 2 shows an almost linear response between 2.1 and 1.3 nC. The electric field intensity was not sufficiently high for complete ion collection below 1.3 nC, while above 2.1 nC the electric field was large enough to cause ion multiplication [4]. When the charge falls below 1.3 nC, the dosimeter can be recharged by the usual procedure, after a heat treatment of 120°C for 10 min. The observed reproducibility after nearly 50 recharge cycles was better than 5%. Natural discharge (fading) studies showed that the charge loss is of the order of 1% per month measured over a 46 d period, in ambient conditions of temperature (20–25°C) and relative humidity (60–70%), for electret dosimeters with outer jacket [5]. The charge range for linear response is independent of the beta radiation energy.

The results for different radiation field geometries and wall materials of the outer jacket will be presented separately, as follows:

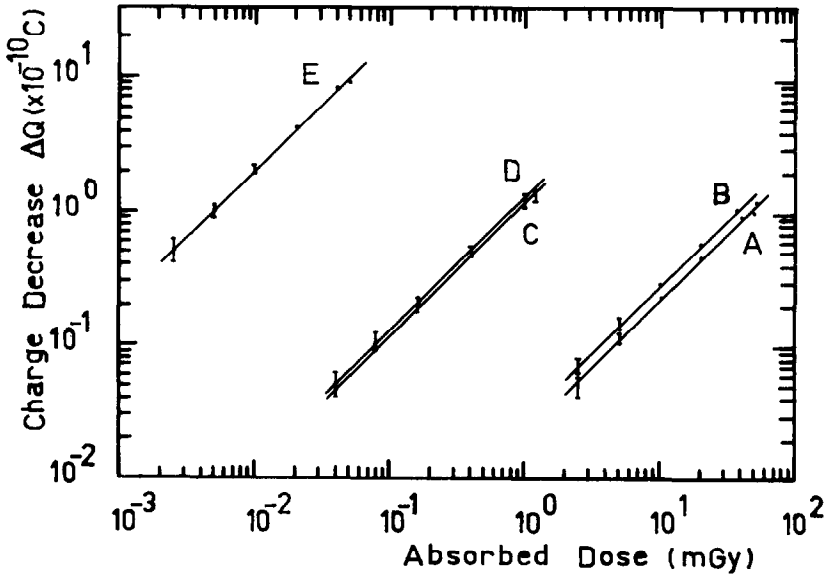

Fig. 3. Absorbed dose response. (A) $^{90}Sr + ^{90}Y$ radiation, parallel geometry, lucite jacket. (B) ^{204}Tl radiation, parallel geometry, lucite jacket. (C) $^{90}Sr + ^{90}Y$ radiation, perpendicular geometry, aluminum jacket with longitudinal openings. (D) ^{204}Tl radiation, perpendicular geometry, aluminum jacket with longitudinal openings. (E) $^{90}Sr + ^{90}Y$ and ^{204}Tl radiation, perpendicular geometry, without jacket.

Case 1: Electret axis parallel to the radiation field with lucite jacket. The absorbed dose response to $^{90}Sr + ^{90}Y$ and ^{204}Tl radiation presented a linear behavior between 2.5 and 40 mGy. Fig. 3 (curves a, b) presents the results for the $^{90}Sr + ^{90}Y$ and ^{204}Tl sources. The energy dependence of the electret response was determined by the ratio between the responses to ^{204}Tl and $^{90}Sr + ^{90}Y$ radiations as being 1.23.

Case 2: Electret axis parallel to the radiation field and aluminum jacket. The results were similar to those of case 1.

Case 3: Electret axis perpendicular to the radiation field and aluminum jacket with longitudinal openings. In these conditions the electret detector sensitivity was much higher than in the two previous cases: linearity can be observed between 4.0×10^{-2} and 1.2 mGy. Fig. 3 (curves c, d) presents the results for the $^{90}Sr + ^{90}Y$ and ^{204}Tl sources. The energy dependence of the electret response determined as in case 1 was 1.07.

Case 4: Electret axis perpendicular to the radiation field and lucite or aluminum jackets. In both these cases the detector sensitivity was not high enough for beta radiation detection.

Case 5: Electret axis perpendicular to the radiation field and open detector (without jacket). This special geometry permits maximum charge collection volume, allowing very low absorbed dose determinations: 2.5 μGy, using $^{90}Sr + ^{90}Y$ and ^{204}Tl radiation fields. The absorbed dose response linearity is showed in fig. 3 (curve e) for $^{90}Sr + ^{90}Y$ and ^{204}Tl radiation between 2.5 and 40 μGy. The electret response presented an energy independence in these conditions.

The main advantages of the electret dosimeter studied for beta radiation detection are linear response over a known range, reusability and the fact that the reading does not erase the information. The only disadvantage is the electret's lack of stability against decay during long time storage, in operational ambient conditions.

The highest sensitivity (2.5 μGy) and energy independence was obtained with the special geometry of the electret axis perpendicular to the radiation field and without jacket. An undefined sensitive chamber volume is not useful for dosimetry purposes, because the electret response presents a fast decay with time. This kind of detector is, however, useful when very low dose determinations are carried out in a beta radiation laboratory.

Depending on the beta absorbed dose range, either the parallel or the perpendicular geometry has to be chosen, preferentially both together when the dose range and energy are not known. For beta dosimetry purposes, the perpendicular geometry and aluminum jacket detectors are the most promising.

These aspects make the electret dosimeter useful for several radiation detection applications.

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