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EXPERIMENTAL STUDY OF NON-POWER DETECTORS FOR MEASUREMENT OF GAMMA-RAY DOSE

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Introduction

Irradiation by gamma rays can produce a charge deposition near the interface of materials of different atomic number (Z). The deposition of charge can cause high induced voltages if one of the materials is an insulator. This effect can be in the kilovolt range under conditions using the better insulators. For example, irradiation of a plate of a low-Z insulator which is much thinner than the absorption length of gamma rays but thicker than the maximum range of the electrons produced within it by gamma rays will produce a current of photo- and Compton electrons which runs in the direction of the incident radiation beam. When a perturbating layer of higher-Z material is placed perpendicular to the beam, within the insulator, a space charge will be produced on both sides of the higher-Z layer within the insulator. The accumulation of space charge near the perturbating layer continues with increasing doses until limited by radiation-induced conductivity or the breakdown of the insulator. The phenomena and regulations of charge deposition in higher atomic number materials placed within an insulator and irradiated were studied by S.Kronenberg[1], Jin Shengren[2,3] and others[4–11]. In this paper, the characteristics of non-power detectors with different structures, based on the principle described above, are further studied using macromolecule material as dielectrics.

Experiments and Measurements

The structure of the I-type (common type) parallel-plate non-power detector is shown in Fig.1. By properly changing the shape and size, the U-type (double-ply) detector and the S-type (three-ply) detector are obtained. The I-type parallel-plate non-power detector consists of: a) an internal electrode of a higher-Z material such as Aluminium; b) a dielectric such as polyester film; c) a conducting layer such as Carbon which forms a capacitor together with the internal electrode and the dielectric; d) an induction body of low-Z material such as polythene which produces photo- and Compton electrons when irradiated; e) an outer shell which is connected to the conducting layer; and f) a measuring hole, which is as small as possible.

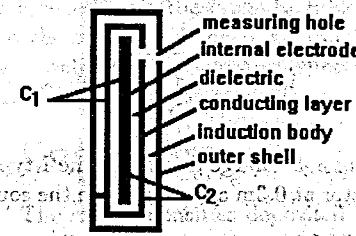

Figure 1 The structure of a parallel-plate non-power detector.

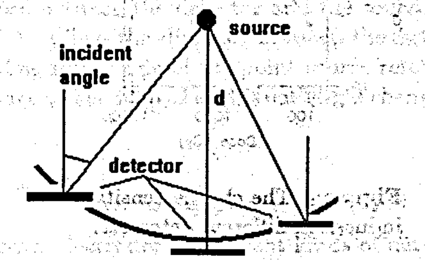

Figure 2 The plane schematic of the experiment.

The gamma ray source used for the measurements is a vertically-placed column-type ^{60}Co source with an irradiation rate of 0.1432 (C.kg^{-1}.s^{-1}). The plane schematic of the experiments is illustrated in Fig.2. Charge densities per unit area (Coulomb/cm^2) induced in the internal electrode by gamma ray are measured with a high input-resistance electrometer (FJ-256, made in China). Time was less than 1 minute from the stop of irradiation to the start of measurements with the electrometer. The measurement uncertainty is much less than ±10%, which consists of the inherent detector errors and errors of the measuring system.

Results and Discussions

The I-type, U-type and S-type parallel-plate non-power detectors were simultaneously irradiated. The detectors were placed 0.3 m from the source, where the dose rate was 1.99 (Gy/s). The charge densities per unit area induced in the internal electrode by ^{60}Co gamma rays of different doses were measured with the electrometer. The results of the measurements are shown in Fig.3. It can be seen from Fig.3 that positive charges are deposited in the insulated internal electrode in all cases though the shape and structure of these detectors are different. The charge densities deposited in the internal electrode are nonlinear with respect to irradiation dose, and all of them decrease after tending towards saturation. The order of saturation dose corresponding to the saturation charge densities of different detectors is S-type>U-type>I-type.

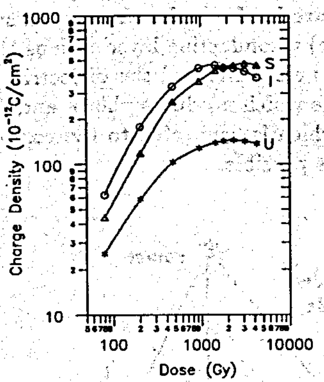

Figure 3 The charge density induced in different detectors.

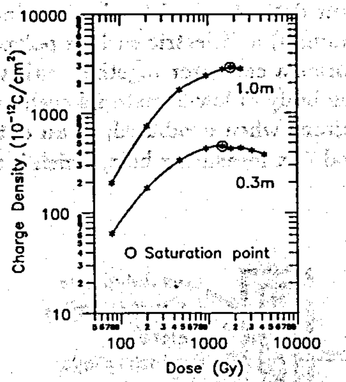

Figure 4 Charge density of the I-type detector at 0.3m and 1.0m from the source.

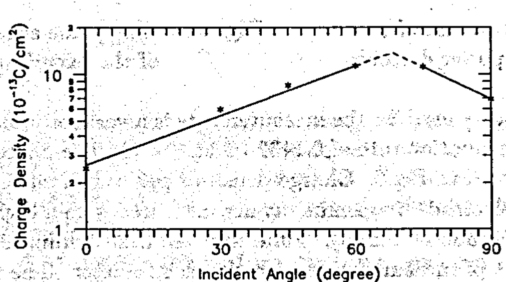

Figure 5 The charge density at various incident angles.

An I-type parallel-plate non-power detector is placed 0.3 m and 1.0 m respectively from ^{60}Co gamma ray source and irradiated at the same dose each time. The charge densities per unit area induced in the internal electrode at different distances from the source were measured with an electrometer as a function of irradiation dose. The results, which appear in Fig.4, show that the charge densities deposited in the internal electrode are obviously different, because of the different distances between the detector and the source though the irradiation doses were the same. The saturation doses are definitely dependent on the distance between the detector and the source. The farther the detector is from the source, the more parallel the gamma rays from ^{60}C0 point source are, the more linearly the charge density deposited in the internal electrode changes with irradiation dose.

To investigate the directionality of parallel-plate non-power detectors to depositing charge, the charge densities induced in the internal electrode were measured at the same distance, 2.0 m, from the ^{60}Co gamma ray source, but at various gamma ray incident angles, 0^0,30^0,45^0,60^0,75^0 and 90^0, respectively. The inherent capacitance of the I-type detector was 22500 (pf), and the area of the internal electrode was 160 (cm^2). The irradiation dose was 26 (Gy) each time. The results of the measurements, which appear in Fig.5, indicate that the parallel-plate non-power detector is quite sensitive to the incident direction of gamma rays from this source. The charge deposition has an obvious directionality with the existance of a maximum value between 60^0 and 75^0. The reason why, for this kind of source, the charge deposition in internal electrodes irradiated at the same dose is dependent on the distance between the detector and the source may be inferred from these results (see Fig.4). When the distance between the detector and the source is changed, the corresponding solid angle of the point source related to the parallel-plate non-power detector changes, therefore, the incident angle changes as well.

Conclusion

The charge densities deposited in internal electrodes of different kinds of detectors are nonlinear as a function of irradiation dose, and decrease after tending towards saturation. In the case of a ^{60}Co gamma ray point source, the charge densities deposited in internal electrodes of detectors are dependent on the distance between the detector and the source and the gamma ray incident angle. As a result, the applications of parallel-plate non-power detectors are limited, but these detectors can be used to distinguish the direction of gamma rays.

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