сообщения
объединенного
института
ядерных
исследований
дубна

E13-93-390

Jin Shengren*, Li Mingfei*

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

*Department of Physics Northeastern Normal University, Changchun, 130024, P.R.China

1993

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 the 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 dose until limited by radiation-induced conductivity or 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[2,3,4] and others[5-12]. In this paper, the characteristics of non-power detectors with different thicknesses of the dielectric and induction body and different ratios of two sided capacitances, based on principle described above, are further studied.

Experiments and Measurements

The structure of an I-type parallel-plate non-power detector is shown in Fig.1. The I-type parallel-plate non-power detector consists of: a) a 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 the capacitor together with the internal electrode and the

dielectric; d) an induction body of a low-Z material such as polythene which produces photo- and Compton electrons when irradiated; e) a outer shell which is connected to the conducting layer; and f) a measuring hole which is as small as possible. The thicknesses of the internal electrode, the dielectric, the conducting layer, the induction body and the outer shell of the I-type parallel-plate non-power detector were 0.4 mm, 20 μm, 10 μm, 1.8 mm and 0.2 mm, respectively. The left-side capacitance of a parallel-plate non-power detector is C_1 (see Fig.1) which consists of the left-side conducting layer and the internal electrode. The right-side capacitance is C_2. The C_1 and C_2 of I-type (common type) detectors are equal because the two sided Carbon-conducting-layer areas of I-type detectors are equal.

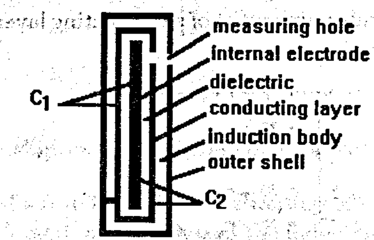

Figure 1 The structure of a parallel-plate non-power detector.

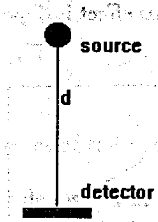

Figure 2 The plane schematic of the experiment.

The gamma ray source used for the measurements is a vertically-placed column-type ^{60}Co source with an irradiation rate at 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 rays were 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 $\pm10\%$, consisting of the inherent detector errors and errors of the measuring system.

Results and Discussions

Based on the I-type parallel-plate non-power detector, the right-side capacitance C_2 of the detector (see Fig.1) will be changed when only the right-side Carbon conducting layer area is changed and other conditions are not changed. Some parallel-plate non-power detectors with a different capacitance C_2 have been made according to the following ratios of the two sided capacitances of a parallel-plate non-power detector

$$K = C_2/C_1 = 0,\ 1/3,\ 1/2,\ 2/3 \text{ and } 1.$$

The charge densities induced in the internal electrodes of detectors were measured as a function of the ratio of the two sided capacitances. Detectors were placed 1.3 m from the gamma-ray source and irradiated at a dose of 20 (Gy). The gamma rays were from the left (towards C_1, see Fig.1) and the right (towards C_2) of detectors, respectively. The experimental results are shown in Fig.3. It can be seen from Fig.3 that the polarities of charges deposited in the internal electrodes of the detectors are all positive for irradiation incident from the left (towards C_1), but the polarity of charges deposited in the internal electrode reverses for irradiation incident from the right (towards C_2) when K is between 2/3 and 1. The charge density deposited in the internal electrode of the detector when K=0 is the plus or minus maximum value for the two cases (towards C_1 or C_2). It means that the charge density deposited in the internal electrode of a detector is maximum when there is no Carbon conducting layer on the left of the detector (see Fig.1). The experimental results have proven that a Carbon conducting layer stops the transference of photo- and Compton electrons produced in induction body. This effect is dependent on the atomic number (Z) of a conducting layer.

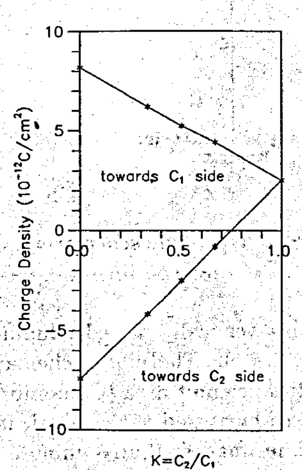

Figure 3 The charge density with different capacitance ratios.

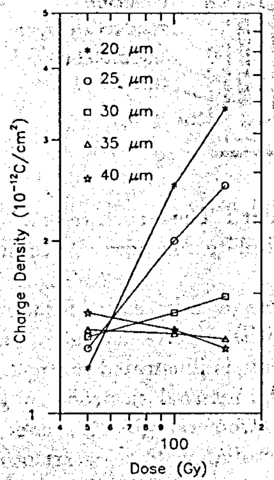

Figure 4 The charge density with different thicknesses of the dielectric.

In order to study the influence of dielectric thickness on the charge density deposited in the internal electrode of a detector, some parallel-plate non-power detectors with different dielectric thickness have been made, based on the I-type detector. The dielectric thicknesses were 20 μm, 25 μm, 30 μm, 35 μm and 40 μm, respectively. Detectors were irradiated at a distance of 1.2 m from the source. The results of these measurements, which appear in Fig.4, show that the charge density deposited in the internal electrode of the detector, for which the dielectric thickness is 35 μm or more, reaches saturation at about 50 (Gy). The charge density deposited in the internal electrode of the detector,

for which the dielectric thickness is 20 μm, goes up steadily with increasing irradiation dose, and the linearity of the curve is much better. However, the dielectric thickness of the detector is too thin to ensure its insulating strength. The experiment indicates that the dielectric thickness must be thicker than 15 μm.

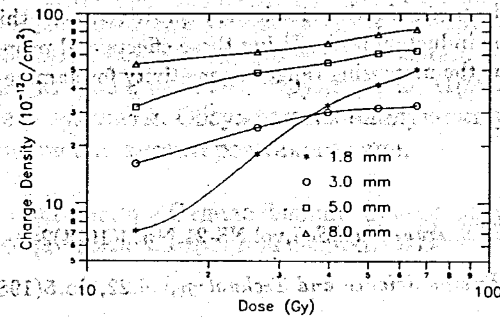

Figure 5 The charge density with different thicknesses of the induction body.

To investigate the relationship of the charge density deposited in the internal electrode and the thickness of the induction body of a detector, which structure is shown in Fig.1, several parallel-plate non-power detectors with different thicknesses of induction body have been made, based on the I-type detector. The thicknesses of inducton bodies were 1.8 mm, 3.0 mm, 5.0 mm and 8.0 mm, respectively. Detectors were placed 2.8 m from the source and irradiated at a dose of 13.2 (Gy) each time. The experimental results, which appear in Fig.5, indicate that the thinner the induction body of the detector, the more linear the curve, and the larger the changing gradient. In other words, the thicker the induction body of the detector is, the faster the charge density deposited in the internal electrode of the detector approaches saturation, and the smaller the changing gradient of the curve is. The charge density deposited in the internal electrode of a detector with a thick induction body is larger in the low dose range than that deposited in the internal electrode of the detector with a thin induction body, but smaller than that deposited in the internal electrode of the detector with a thin induction body with an increase of irradiation dose. When the thickness of the induction body of a detector is equal to the maximum range of the secondary electrons produced within the polythene material, charges can be deposited in the internal electrode of detector and the charge deposition is close to linearity as a function of irradiation dose.

Why does the thickness of the dielectric and the induction body of the detector have such a great influence upon the linearization of the charge deposition? It can be explained by "the space-charge layer". If the dielectric of a detector is too thin, the space-charge layer is unable to thicken because of the limit of the dielectric thickness, therefore the action of the space-charge layer to stop charge transference is small, and linearity is good. If the induction body of a detector is too thick, the probability of forming a space-charge layer is great becasue of the large number of secondary electrons produced in the induction body.

Conclusion

The Carbon-conducting-layer of a parallel-plate non-power detector can prevent the photo- and Compton electrons produced in the induction body from transferring, and this is dependent on the atomic number (Z) of the conducting layer. The charge density deposited in the internal electrode of a detector is very sensitive to the thickness of the detector's dielectric and the induction body. Using these effects and properly selecting the materials for a detector, the measuring range or sensitivity for gamma-ray dose can be promoted.

References

[1] S.Kronenberg,et al.,*IEEE Trans.Nucl.Sci.*,vol.NS-21,**No.6**(1974)243

[2] Jin Shengren,*Atomic Energy Science and Technology,*vol.22,**No.5**(1988)623 (*in Chinese*)

[3] Jin Shengren,*Atomic Energy Science and Technology,*vol.23,**No.2**(1989)47 (*in Chinese*)

[4] Jin Shengren,Li Mingfei and Bai Jinchang,1st Yanbian International Conference on Modern Physics,Yanbian,1990,Published by World Scientific Publishing Co.Pet.Ltd

[5] T.A.Dellin,et al.,*IEEE Trans.Nucl.Sci.*,vol.NS-21,**No.6**(1974)227

[6] L.D.Singletary,et al.,*IEEE Trans.Nucl.Sci.*,vol.NS-21,**No.6**(1974)291

[7] A.R.Frederickson,*IEEE Trans.Nucl.Sci.*,vol.NS-22,**No.6**(1975)2556

[8] A.R.Frederickson,*IEEE Trans.Nucl.Sci.*,vol.NS-23,**No.6**(1976)1867

[9] J.Pigneret and H.Stroback,*IEEE Trans.Nucl.Sci.*,vol.NS-23,**No.6**(1976)1886

[10] A.R.Frederickson,*IEEE Trans.Nucl.Sci.*,vol.NS-24,**No.6**(1977)2532

[11] V.W.Pien,et al.,*IEEE Trans.Nucl.Sci.*,vol.NS-25,**No.6**(1978)1586

[12] W.L.Chadsey,*IEEE Trans.Nucl.Sci.*,vol.NS-25,**No.6**(1978)1591

Received by Publishing Department on October 29, 1993.