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CADMIUM SULPHIDE THIN FILM FOR APPLICATION IN GAMMA RADIATION DOSIMETRY

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ABSTRACT

Cadmium Sulphide (CdS) thin film was prepared using pyrolytic spraying technique and then irradiated at varied gamma dosage. The CdS thin film absorption before gamma irradiation was 0.6497. Absorbed doses were computed using standard equation established for an integrating dosimeter. The plot of absorbed dose against gamma radiation- induced change in absorption is linear. A calibration curve for the development of a prototype cadmium sulphide – based gamma radiation dosimeter was proposed.

KEYWORDS: Cadmium Sulphide, Absorbed Dose, Radiation Dosimeter, Gamma radiation, Band Gap Energy.

INTRODUCTION

Semi-conductor radiation detectors in current use are manufactured either from silicon or germanium. These materials have excellent charge transport properties, which allow the use of large-crystals without excessive carrier losses due to trapping or recombination. However, their limitations include the large thermally generated leakage current which requires a cryostatic condition when they are in use (Adetunji et al 2000, Adetunji et al 1992).

In principle, some other semi-conductor materials with wider band gap (>1.5eV) could reduce the bulk of the generated leakage current so that measurement at room temperature could be possible. Great attention has therefore been focused on seeking other suitable semi-conductor materials which incorporate at least one element of high atomic number. Up to date, three specific compound semi-conductors have received the most attention as potential room-temperature radiation detectors. These are cadmium telluride (CdTe), mercuric iodide ($Hg1_2$) and gallium arsenide (GaAs). The larger band-gap energy (1.47eV) and the higher probability of photoelectric absorption per unit path length (roughly 4 to 5 times higher than Ge, 100 to 200 times higher than Si) obtained in CdTe have made the material more suitable for the construction of a compact gamma ray detector capable of operating at room temperature (Adetunji et al 2002, Tsoul Fanidis 1983).

Studies on Cadmium Sulfide (CdS) also become important because of its larger band-gap energy (2.5eV) than that of CadmiumTelluride (CdTe), (Ge) or silicon (Si). The wide band-gap energy of 2.5eV allows room-temperature operation without excessive thermally generated noise (Tsoul Fanidis 1983). Analysis of performance characteristics of Cd^{2+}/Cu^{+} p-n junction after gamma irradiation indicates a dose-dependent improved performance, although at the expense of cell life (Fraunk et al 1968, Frunz et al 1958). In this present work, an attempt has been made in the development of a CdS-based gamma radiation detector and dosimeter.

EXPERIMENTAL TECHNIQUES

The preparation of CdS thin film and the Cd^{+}/Cu^{+} system has been previously reported (Fraunk et al 1968, Frunz et al 1958). CdS thin film sample was irradiated at an initial dose of 0.168kGy, and subsequently at 0.84, 1.5 and 2.85kGy respectively, the gamma dose rate being 0.6 Gray per second in a Cobalt – 60 AECL Gamma cell 220 Irradiator. Absorption data were obtained before and after irradiation at the respective doses. Changes in absorption data induced by irradiation were determined. A Varian UV-Visible spectrophotometer at wavelength range 360 to 190mm was employed in this analysis. Absorbed doses were obtained using standard equation established for integrating dosimeter.

RESULTS

Figure 1 shows the calibration graph based on change of absorption induced by gamma irradiation. In Figure 2, a sketch of the proposed CdS based dosimeter is presented. Using the Cd^{2+}/Cu^{+} system characteristics, the sensitivity was determined as 7.6volts per kGy. The change in open circuit voltage induced by gamma irradiation is 0.0025mV while the CdS thin film absorption before gamma irradiation is 0.6497. The relation

$$\frac{(X_0 - X_1)V_0}{(K)\ X_0} = \text{Absorbed Dosage}$$

where

X_0 = Absorption before irradiation
X_1 = Absorption after irradiation
V_0 = Open Circuit Voltage
K = Cd^{2+}/Cu^{+} Sensitivity (V/kGy)

was applied to determine the absorbed gamma dose. A proposed relationship exists between the change in open circuit voltage induced by radiation and the change in dosage.

DISCUSSION

Cadmium Sulfide thin film has been known for its characteristic properties in radiation detection and dosimetry applications in recent years (Adetunji et al 2000, Adetunji et al 1992, Adetunji et al 2002). CdS, as a compound semi conductor materials, shows similar characteristics with Cadmium Telluride because of its larger band-gap energy than those of the popular germanium and silicon counterparts (Tsoul Fanidis 1983, Frunz et al 1958). The operation of the CdS based semi conductor detector depends on the region of the p-n junction where the electric field exists. Electron and hole pairs produced when radiation particles impinge on the detector in the p-n junction region find themselves in an environment similar to what electrons and ions experience in a plate ionization chamber. However, there are

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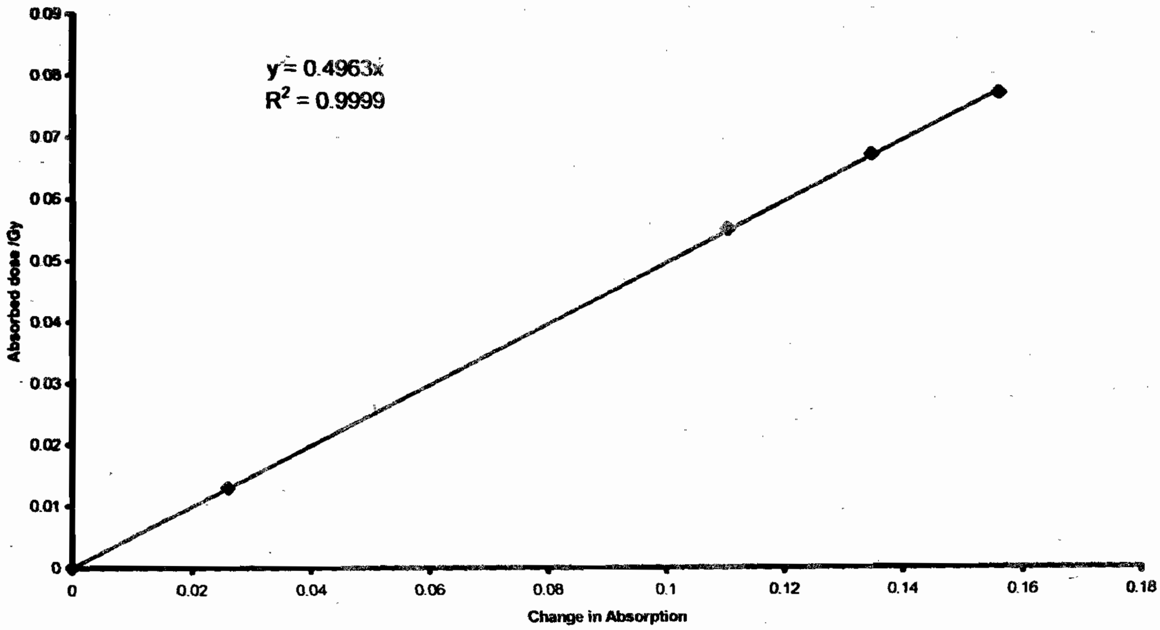

Figure 1 : Graph of change in absorption against absorbed dose

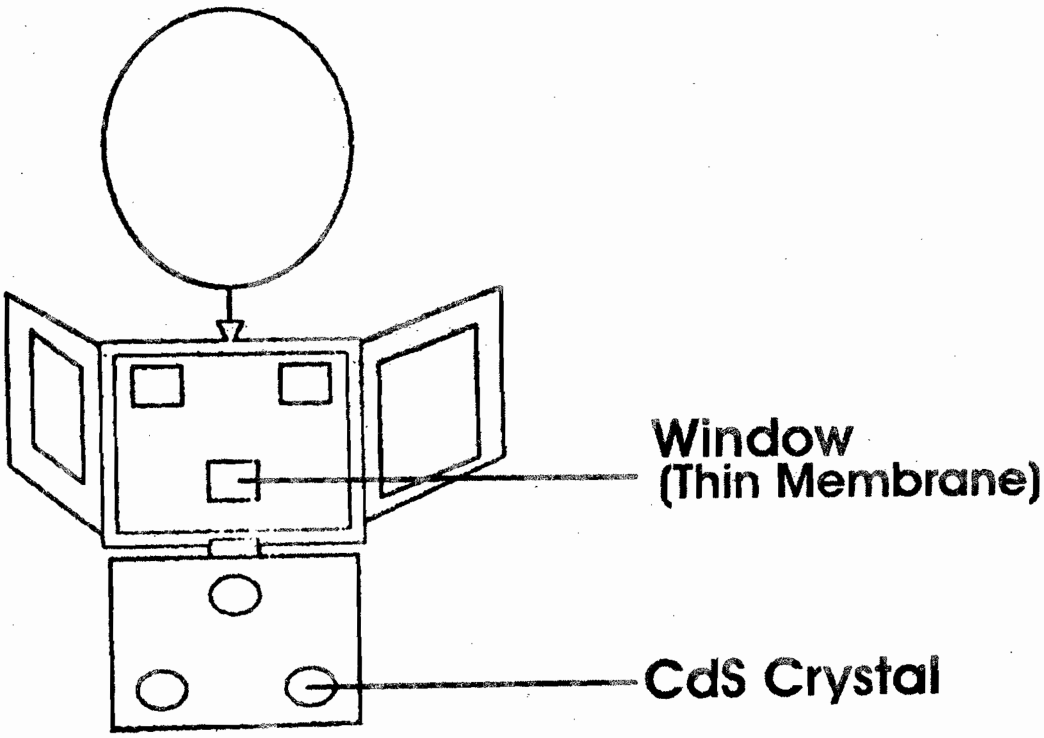

Figure 2: Drawing of the proposed dosimeter badge

some differences. The proposed relationship between the change in open circuit voltage induced by irradiation and the change in radiation dosage has been employed in the determination of the Cd^{2+}/Cu^{+} system sensitivity (Frunz et al 1958). The conversion of the absorbed dose to the voltage term using the Cd^{2+}/Cu^{+} system sensitivity provides support for the proposed relationship between change in open circuit voltage and the change in irradiation dose [Table2]. It can be noted that radiation damage will limit the life span of semi conductor detectors. Crystal defects affect the performance of the detector because they may act as trapping centers for electrons and holes or they may create donor or acceptor states (Fraunk et al 1968, Frunz et al 1958).

Table 1: Absorption data before and after gamma irradiation

D/Gy	X_0	X_1	ΔX	A/Gy
0	0.6497	-	-	-
167.6	"	0.6757	0.026	0.013
838	"	0.7600	0.1103	0.055
1508	"	0.7843	0.1346	0.067
2849	"	0.8056	0.1559	0.077

D = Gamma Dosage
X_0 = Absorption before irradiation
X_1 = Absorption after irradiation
ΔX = Change in Absorption induced by irradiation
A = Absorbed Dose

Table 2: Conversion of Absorbed Dose to Voltage Term

A/Gy	V	D/Gy
0.013	9.88×10^{-5}	167.6
0.055	1.18×10^{-4}	838
0.067	9.09×10^{-4}	1508
0.077	9.352×10^{-4}	2849

V =Voltage Cd^{2+}/Cu^{+} Sensitivity = 7.6v/kGy

CONCLUSION

(1) The application of Cadmium Sulfide thin film in radiation dosimetry has been reported.
(2) Calibration graph has been proposed using absorption data obtained before and after gamma irradiation.
(3) A relationship has been proposed between the change in open circuit voltage induced by irradiation and the change in gamma dosage.
(4) A prototype CdS based radiation dosimeter has been proposed.

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