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Contact technology and energy resolution of CdTe junction detectors

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Abstract

Cadmium telluride (CdTe) has been regarded as promising semiconducting materials for hard X-ray and γ -ray detection. Inexpensive, fast and good resolution CdTe junction detector technique has been developed. A state- of – the -art simple nondestructive procedure for junction fabrication is given. A performance comparison of different CdTe junction detectors exposed to ^{57}Co source has been performed. When using a graphite blocking contact, a significant improvement in the spectral properties of the CdTe detector was attained as compared to other rectifying contacts. The diodes clearly demonstrated their gamma radiation detection capability by resolving energy peaks from ^{57}Co radioisotope at room temperature measurements. The results also demonstrate, for the first time to our knowledge, a junction with no polarization effect.

Keywords: Detector, hetrojunction, nuclear radiation, energy resolution.
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1. Introduction

Cadmium telluride and related compound semiconductors are very attractive materials for the next generation of gamma-ray detectors (1-4). They have high stopping powers comparable with those of NaI(Tl) and CsI(Tl) (5), high average number of e-h pairs (22,000 for100 keV gamma-rays) and low theoretical energy resolution of 500 eV at 100 keV (6). To attain such resolution, the reduction of the electronic noise, which is strongly dependent on the leakage current, is the most important factor (1). The most promising solution in the contact technology (contact material and deposition technique) is by making a barrier detector (Schottky, p-n junction or hetrojunction) on one side and ohmic contact on the other side (7-9). Thermal diffusion of indium and laser annealing of deposited In layer are commonly used, where indium is diffused inside the crystal (9,10). Thermal diffusion suffers from the formation of cadmium vacancies and breaking of some complex bonds (4) whereas laser annealing produces certain type of defects (11). This paper describes the performance of a new CdTe detector prepared by simple, fast and cheap method for nuclear spectroscopy. It addresses strictly the spectroscopic performances with other junction detectors. we try to re-evaluate and discuss the effect of different blocking contacts on the detectors energy resolution.

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2. Experimental

The CdTe crystal used here is a polycrystalline p type CdTe, grown by the Traveling Heater Method, manufactured by laboratory PHAS, France. The electrical resistivity of 10^9 Ω- cm is achieved by compensating the native defects with Cl. The entire samples were treated in the same way: first they were lapped on a mechanical polisher with alumina suspension and rinsed in deionized water. The samples were then treated in 10 % bromine-methanol etching solution for 2 min. The CdTe diodes consist of two symmetrical circular contacts of 3 mm diameter separated by (200 – 400)μm thick CdTe with different resistivities . Some show no polarization (the accumulation of charges at the electrodes which reduce the applied electric field in the counter) while others have different degrees of polarization as shown in table (1). The ohmic contacts (negatively polarized) were realized by the reaction of gold chloride drop on one side of the sample for 40 min. at room temperature (12). The blocking contacts (positively polarized) were (thermal p-n junction, metal / CdTe, In_2O_3 / CdTe hetrojunction with two different evaporation rates , polished Al / CdTe and graphite deposited from aquadag) .

Table 1: Physical properties of the used samples.

CdTe crystal	Resistivity (Ω-cm)	polarization	Resolution (keV) for(Al /CdTe polished)
1336	10^{9}	non	6 – 7
1368	$10^{7} – 10^{8}$	low	10 - 20
1377	$\sim 10^{9}$	very high	---
1385	$\sim 10^{7}$	high	---

The output of the detectors was measured using a ^{57}Co source. Output pulses were recorded and analyzed using a preamplifier, a multichannel analyzer and a storage oscilloscope. During the experiment, the gold contact was the entrance window to assure the same relative distance point of interaction in the detectors. The carrier transport property of the junction was investigated at room temperature by means of current-voltage (I-V) measurements.

3. Results

With polished surface detector a considerable amount of the applied voltage drops across the high resistive damaged layers of the detectors as shown in figure (1). This results in the accumulation of charges at the electrodes which modifies the electric field in the counter (13) and encourages the polarization effect (14,15). For these reasons and to avoid such problems, most of the diode structure is prepared on an etched surface, where at least 50 μm thickness of the material on both faces is removed.

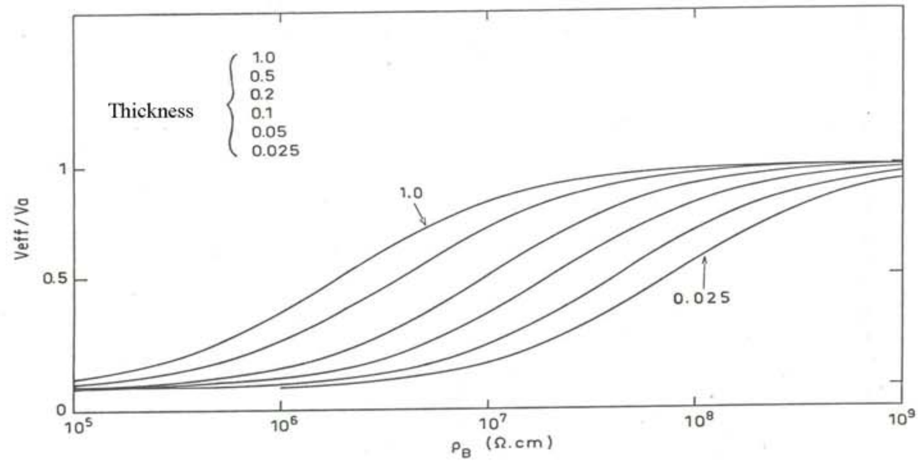
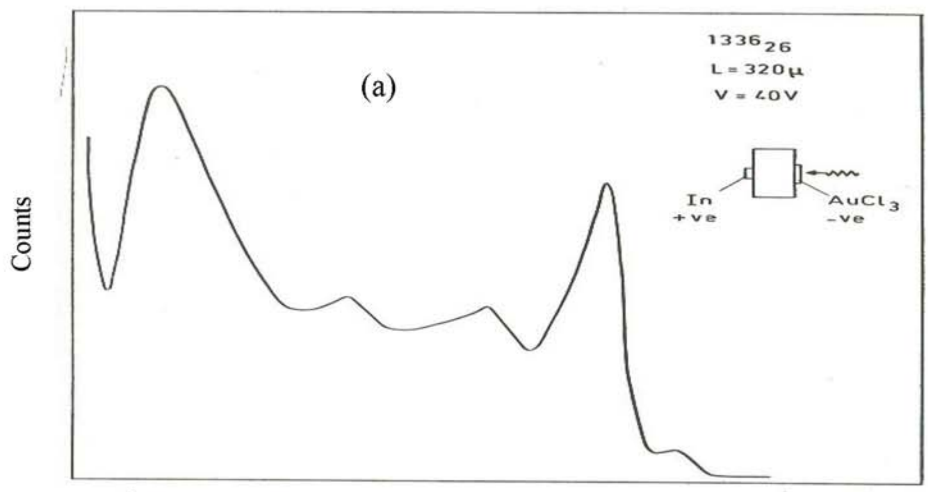
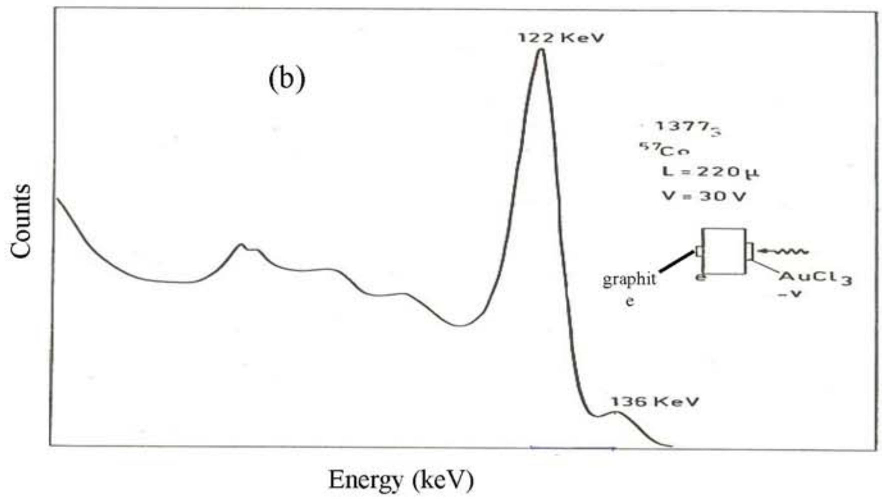
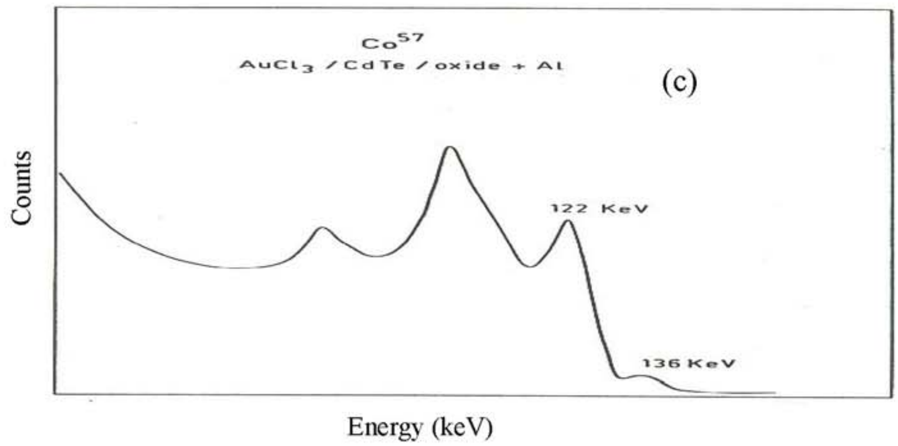


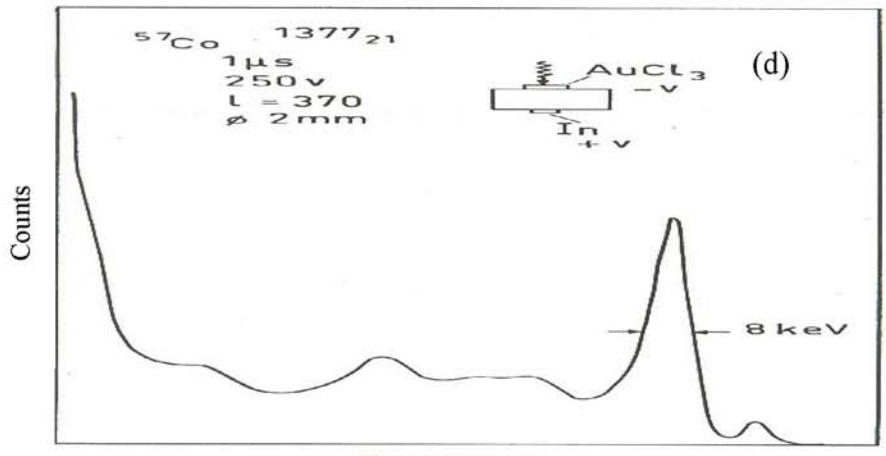
Fig. 1: The Influence of high resistance damaged layer on the effective applied voltage Veff as a function of crystal resistivity ρ and thickness d

Figure 2 (a-e) shows the ^{57}Co spectrum obtained from the diodes at 25 °C taken after 24 h of irradiation. Experimentally from the forward current and by plotting lnI vs. applied voltage , we found that the barrier height values of the evaporated metals on the low resistivity p- type material were around 0.7 eV, and that of graphite close to 0.76 eV. All diodes show very good rectification properties as a result of the junction formed. The reverse bias current is well saturated, whereas the forward bias current increases exponentially.




122 KeV
(b)
1377
57Co
L = 220 μ
V = 30 V
graphite
AuCl3
-V
136 KeV
Counts
Energy (keV)


Co57
AuCl3 / CdTe / oxide + Al
(c)
122 KeV
136 KeV
Counts
Energy (keV)


57Co 1377
1 μs
250 v
L = 370
ø 2mm
AuCl3
-V
In
+ V
(d)
8 keV
Counts

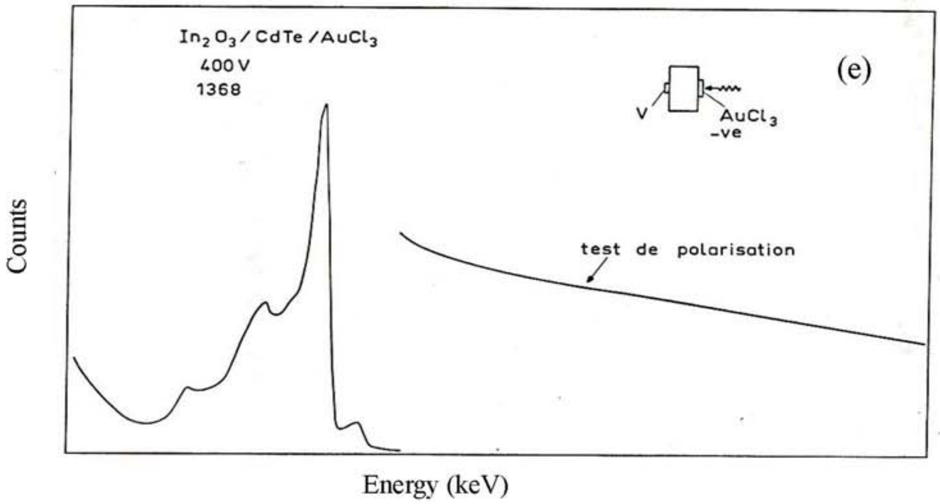


Fig. 2: (a-e): The ^{57}Co response of five different CdTe junction detectors (a) evaporated In / CdTe (b) Droplet of graphite / CdTe (c) Al /oxide /CdTe (d) Thermal n / p (e) Hetrojunction Detectors b,d and e shows the best performance. Detector c has poor performance and Detector a has average performance.

A significant decrease of leakage current is obtained in the reverse bias of the 200-300 µm graphite-CdTe-Au configuration where a current of ~ 10^{-8} A was typically observed at 40V. Table (2) indicates the average electrical field, resolution of 122keV and polarization test performance

Table 2: The physical and indications of the used samples.

Junction structure	Energy resolution (keV) for 122 keV	Mean electrical field (kv / cm)at 1.5 *10 -7 A/cm2	polarization
MS	15	1.5-3	non
MIS	-	4-5	low
p-n junction (thermal)	8	6-9	no
Hetrojunction	12	4	low
Graphite junction	9.6	5-6	no

Radiation detectors performance is limited by both bulk and surface imperfections introduced during the growth, and by the fabrication technique of these devices. The effect of surface imperfections was eliminated by etching with a Bromine Methanol solution, while bulk imperfections of the samples used in this work were consistent with single deep recombination centers of energy 0.7eV, characterized by means of space charge limited current. Detector(**c**)(MIS) has poor performance and shows a degradation of gain with time and resolution (~ 11 keV) . Such behavior could be attributed to excess noise in the oxide layer already observed (15). Detector (a) (MS) of the evaporated indium having electrical properties comparable with those of deposited graphite both having circulating current 10^{-8} A at 40 V) shows energy resolution of (15 keV) with no polarization . Schottky junction, prepared from suspension graphite detector (b), has (9.6 keV) energy resolution with no trace of polarization although the starting material is highly polarized.

The pulse height spectra are higher than the pulse height of other junction detectors which indicates lower dark noise of the graphite detector and lower fluctuations in the collected charge due to trapping of charge carriers in the detector and better charge collection

Thermal p-n junction, made by thermal heating of 500 nm evaporated In layer at 160 ^{0}c for 40 min. under nitrogen flow, shows noticeable improvement as compared to unheated detectors. A typical energy resolution of 8 keV was observed without polarization as shown in Figure (d). The enhancement, in both electrical and detection properties, are related to the (0.8- 0.9 eV) built - in potential accompanied the depletion layer formation. Good energy resolution of (10 keV) was obtained from the hetrojunction made by an electron gun evaporation of 40 nm thick indium tin oxide layer (usually used in making solar cells (15)) at evaporation rate less than 0.3 nm /s. From the low resistivity material measurements, the hetrojunction potential barrier height was estimated to be 0.85-0.95 eV.

4. Conclusion

In this paper, we have presented the results of a systematic study of the performance of CdTe detectors depending on contact materials and contact deposition. We report a significant improvement in the spectral properties of CdTe detectors by means of a graphite blocking contact. The advantage of the graphite contact is in it's fabrication procedure which does not involve a multi processes nor a vacuum or high purity metals, besides, it is very cheap and time saving, of an energy resolution comparable to that of diffusion p-n junction and better than that of the MS.

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