98 URC118

Surface Passivation of CdZnTe Detector by Hydrogen Peroxide Solution Etching

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Abstract

The spectral resolution of room temperature nuclear radiation detectors such as CdZnTe is usually limited by the presence of conducting surface species that increase the surface leakage current. Studies have shown that the leakage current can be reduced by proper surface preparation. In this study, we try to optimize the performance of CdZnTe detector by etching the detector with hydrogen peroxide solution as function of concentration and etching time. The passivation effect that hydrogen peroxide introduces have been investigated by current-voltage (I-V) measurement on both parallel strips and metal-semiconductor-metal configurations. The improvements on the spectral response of ^{55}Fe and ^{241}Am due to hydrogen peroxide treatment are presented and discussed.

Introduction

Recently, a new generation of x-ray and gamma-ray imaging detectors and spectrometers based on CdZnTe (CZT) has been realized[1-4]. CZT detectors have rapidly captured a significant interest due to a compact size, good energy resolution and room temperature operation capability. Although the physical properties of the bulk crystal set a fundamental limit to the performance of the detector, it is the fabrication process that determines the actual performance of the device. Of great importance is surface passivation. This is because unpassivated surfaces usually lead to high surface leakage current and l/f noise current which significantly affect the overall performance of the detector via spectral broadening.

Due to a very limited number of reports on CZT surface passivation especially with regard to detector performance, an in-dept investigation on this issue is needed. in this work, we present a study of surface passivation of CZT detectors by hydrogen peroxide (H_2O_2) solution etching. I-V curves as well as x-ray and gamma-ray spectral response of CZT detectors treated with different H_2O_2 concentrations and different etching times were compared with that of the untreated sample to reveal the passivating effect of H_2O_2 cm CZT detector performance.

Experimental

The samples used in this investigation were grown by the High Pressure Bridgman method and purchased from eV-Products, Inc. They were first polished on a mechanical polisher with 0.05 µm particle size alumina suspension and then rinsed with methanol. The samples were then chemically etched in 5°/0 Bromine in methanol for 2 minutes and washed in methanol. This chemical etching process is necessary to ensure room temperature response of CZT detectors[5,6]. Au contacts were then deposited by the thermal evaporation method immediately after the chemical treatment. Pt leads with a diameter of 0.01 in. were next attached to the contacts using Aquadag (graphite suspension in water). The contact areas were then covered with "Humiseal" to provide mechanical stability. In addition to the Metal-Semiconductor-Metal detector configuration, we also fabricate a one-size parallel strips configuration to measure the interstrip surface leakage current before and after the oxidation. The devices were finally treated with hydrogen peroxide aqueous solution at different concentrations and etching times. The passivated areas are those regions on the CZT surface just outside the metal contacts.

For I-V characterization, each sample was mounted on a Teflon holder and then placed in a closed aluminum testing box. The measurements were carried out in room temperature using a Keithley programmable electrometer (Model 617) in conjunction with a Bertran high voltage power supply (Series 225). The data acquisition was computer controlled via a GPIB interface.

For the detector performance study, ^{55}Fe and ^{241}Am sources were used. The source was placed 1 mm away from the detector surface. The detector was mounted on a specially designed boron nitride holder and inserted in an aluminum testing box from which the electrodes were connected to an EG&G preamplifier (Model 142A). The charge pulse produced in the detector volume by absorption of gamma radiation was converted to a voltage pulse. The signal was further amplified by a Tennelec TC 242 shaping amplifier before it was fed into a multichannel analyzer for spectral analysis.

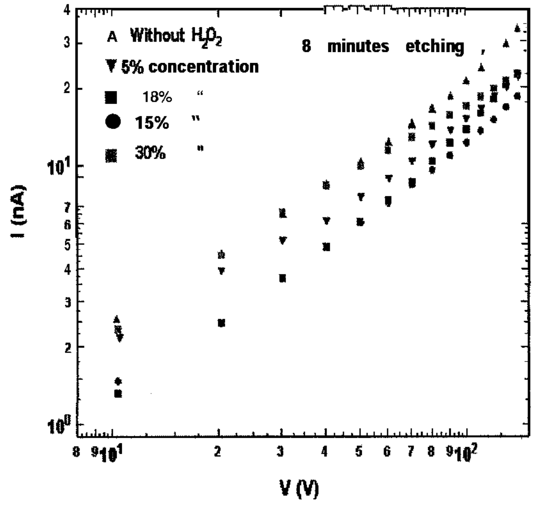

Fig. 1 Comparison of I-V curves of CZT detector treated by different concentrations of H_2O_2 aqueous solution for 8 minutes.

Results and discussion

Shown in Fig. 1 are the I-V curves of CZT detectors treated with different concentrations of H_2O_2 for 8 minutes. Obviously, the treatment leads to a lower level of the leakage current, as much as 43% decreasing for 15% H_2O_2 solution. Consequently, the energy resolution in spectral response is significantly enhanced as shown in Fig. 2 where the x-ray photopeaks and the 59.6 keV gamma peak of ^{241}Am source are well resolved after H_2O_2 passivation (FWHM at 59.6 keV

Table 1. Comparison of I-V and ^{241}Am gamma spectrum results of CdZnTe detector treated by different concentrations of H_2O_2 (for 8 minutes).

H_2O_2 concentration (% vol.)	Current density at E = 1000 V/cm (nA/cm^2)	%FWHM at 59.6keV ^{241}Am photopeak (100V bias)
without H_2O_2	303	11.7%
5%	**214**	10.45%
1 0%	194	**8.8%**
15%	172	7.6%
30%	239	10.2%

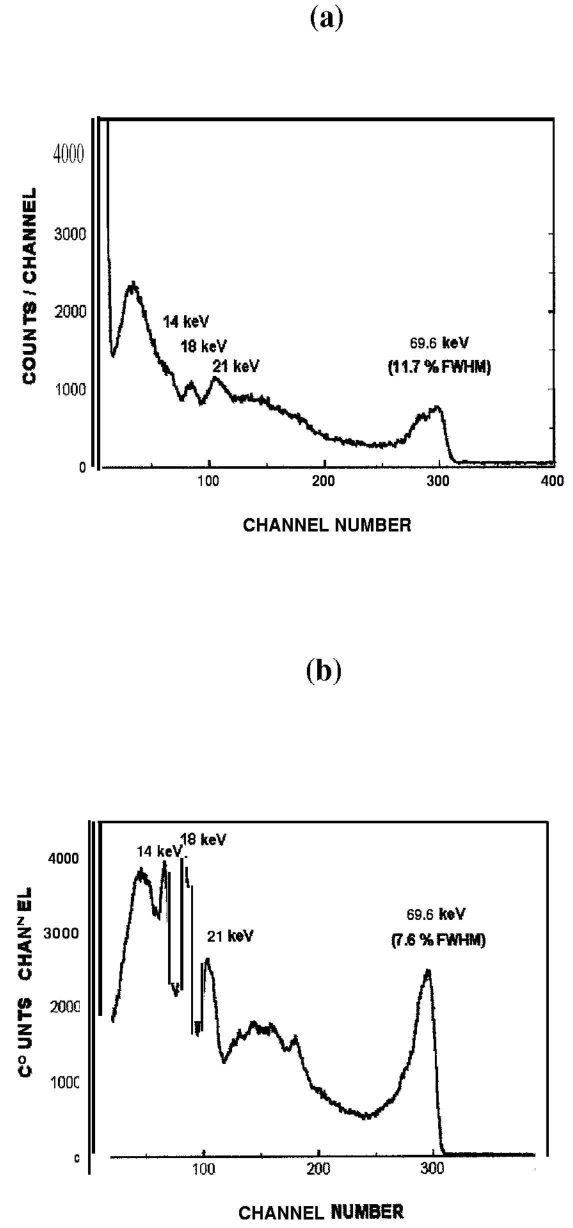

Fig.2 ^{241}Am spectrum of CZT detector treated by concentration of H_2O_2 in 8 minutes (room To, A=0.07 cm^2, L=0.08 cm, 100V bias, 100s accumulation time, 2 μs peaking time) :
(a) untreated, (b) 15%.

improves from 11.7% to 7.6%). A summary of I-V measurements and ^{241}Am spectral responses of CZT detectors as a function of H_2O_2 concentration is shown in Table 1.

An interest phenomena can be observed is that the beneficial effect of surface oxidation of CZT detector via H_2O_2 seems to have a threshold level, beyond that the" result can be worsen. This is evidenced by a higher level of leakage current and a worse energy resolution of the sample treated with 30% concentration compared to that corresponding to 15°/0 concentration as shown in Fig. 1 and Table 1.That is to say, at higher concentration of H_2O_2, the passivating effect seems to be less effective.

This phenomena can be even more easily seen when we compare the I-V curves and spectral responses of CZT detector treated with the same concentration (1 5°/0) of H_2O_2 but at different etching times. The passivating effect seems to be very time dependent as shown in Fig. 3 and Fig. 4 where the detector leakage current and the interstrip surface leakage current are measured as a

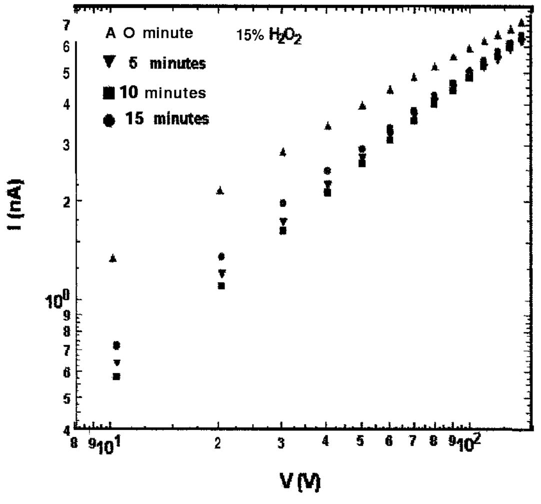

Fig.3: Comparison of I-V results of CZT detector passivated by 15% H_2O_2 aqueous solution in different times.

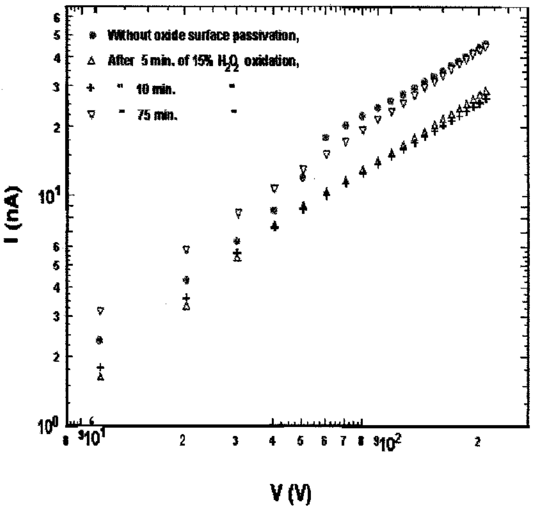

Fig.4 : Inter-strip (2mm) surface leakage current measurements of CZT passivated by 15% H_2O_2 aqueous solution in different times.

Table 2. Comparison of I-V, ^{55}Fe and ^{241}Am spectral results of CdZnTe detector passivated by 15% H_2O_2 in different times.

Oxidation time (minutes)	Current density at 100V bibs (nA/cm^2)	%FWHM at 5.9keV ^{55}Fe photopeak (at 100V bias)	%FWHM at 59.6keV ^{241}Am photopeak (at 100V bias)
0	85	36%	8.2%
5	74	34%	6.7%
10	69	33%	6.7%
15	72	3594	7.9%

function of H_2O_2 etching time respectively. After a period of about 10 minutes, the leakage current can no longer be reduced. In fact, as can be seen in Fig. 3, the result is worsen after 15 minutes and it is much worse for very long etching time as shown in Fig. 4 for the 75 minutes etching sample. The improvement in leakage current due to passivating effect and the time dependence phenomena is also consistent with detector performance as shown in Table 2 where %FWHM at 5.9 keV ^{55}Fe photopeak and 59.6 keV ^{241}Am photopeak of CZT detectors at different etching times are compared. This threshold effect of surface passivation has also been observed for CZT detectors passivated by a different method of oxidation, via low energy atomic oxygen bombardment[7].

The reduction of the leakage current can be attributed to the insulating oxide layer generated. The oxide species has been identified as mainly TeO_2[8]. Other possibilities are $CdTeO_3$ and $ZnTeO_3$. However, the amorphous oxide generated can be any of a variety of ternary compound of the form $[CdTe]_{1-x}O_x$ with variable bandgap depending on the amount of oxygen presented in the generated film[9,10]. At higher H_2O_2 concentration, especially at longer etching time, some nonstoichiometric and more conductive oxide species may have been formed and consequently caused a degrading effect on the oxidized CZT detectors and this may explains the worsening effect observed in this investigation.

Summary

In conclusion, the results reported in this investigation have clearly demonstrated the important role of surface passivation on CZT detector performance. The study shows that the beneficial passivating effect of surface oxidation of CZT detector via H_2O_2 aqueous solution etching is strongly etching-time and concentration dependent. Finally, the study suggests that a 15% H_2O_2 treatment for 8 minutes will results in optimum passivation for room temperature CZT radiation detectors.

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Biography

Miguel “Hayes is a graduate student in the Master degree program in Physics at Fisk University. He has been involved in CZT detectors fabrication and optimization in the NASA/Fisk Center for Photonic Materials and Devices. He is interested in electronics, solid state physics, devices fabrication and evaluation. He plans to pursue a Ph.D. degree after graduation from Fisk.