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Implementation of a Radiation Hardened Infrared Detector

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1. Introduction

Infrared(IR) detector has many applications in medical astronomy, industry, earth resource, and energy conservation. Well-known medical applications include thermography in which IR scans of the body detect cancers or other trauma. Nowadays there is a growing interest in the effect of gamma and other ionizing radiation of IR sensor because of the increasing concerns related to the stability of devices in radiation environments such as space and nuclear power plant.

2. ZnS-passivated MCT Sensor and Gamma-ray effects

2.1 Device characteristics

For the best performance IR detector should have noise as low as possible. The performance metric for IR diode detector is the product of the resistance at zero bias times the detector area. This relation can be expressed as

$$R_0 A = \frac{kTp\tau}{e^2 n_i^2 t} \quad (1)$$

where k is the Boltzman constant, T is the temperature, p is the hole carrier concentration, τ is the minority carrier life time, e is the electron charge, n_i is the intrinsic carrier concentration, and t is the detector thickness. To see the radiation characteristics of the IR detector radiation test was performed in gamma-ray field. The sample detector is MCT(HgCdTe) diode with ZnS passivation layer which is most widely used IR sensor. The properties of the used samples are shown in table 1.

Table 1. The specification of MCT IR device with ZnS passivation layer

Sample	Property
Material	$Hg_{1-x}Cd_xTe$
Composition	X = 0.29
Cut-off Wavelength	5.1um at 77K
Conduction Type	p-type
EPD	$< 5e^5 /cm^2$
Junction Area	200 um x 200 um
RoA	1e6 cm^2

2.2 Gamma-ray effects

Radiation test was performed in the high level gamma-ray(^{60}Co) test facility in KAERI. The irradiation dose rate was 2kGy per hour, and the test duration was 5 hours.

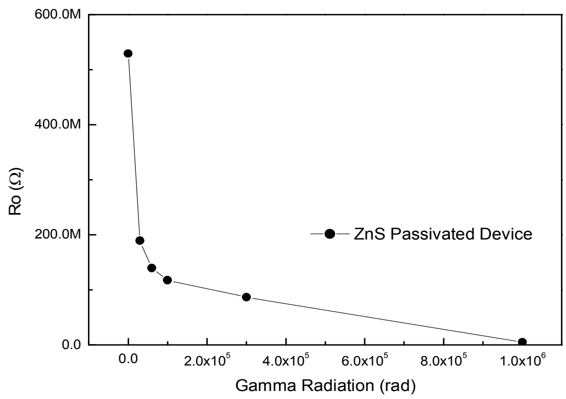

Fig. 1 The variation of the Ro to the gamma-ray dose

Figure 1 shows the radiation test results in the variation of R_0 value. The R_0 value is diminished to one fifth at 3kGy and to one tenth at 10kGy irradiation dose respectively. From those results we can assure that the performance of the sample degrades to the tendency with those values.

3. Radiation hardening with CdTe layer

3.1 MCT diode with CdTe-passivation

The weak characteristics of the sample in the radiation test result were caused by the ZnS passivation layer on it. The layer is tends to very effective at trapping charge, so that property deteriorates the radiation performance.

For radiation hardening of the detector the passivation layer of ZnS was replaced by CdTd which is less affected material by radiation. The CdTe layer is pellet type with 2-3mm diameter and with density 99.999%. Figure 2, the SEM photograph is the shape of an evaporated layer on silicon substrate. It has a columnar structure and 7200A^{O} thickness. EDAX analytical result of it is listed in table 2.

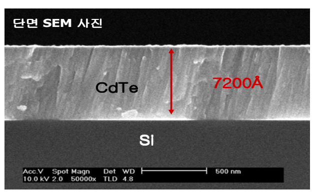

Fig. 2 Cross section photos by SEM

Table 2. Chemical analysis of CdTe using EDAX

Element (atomic no.)	Weight Percent	Norm. Wt Percent	Atomic Percent	Count Err. (sigma wt %)
Cd (48)	46.2506	46.5457	49.7089	0.5623
Te (52)	53.1153	53.4543	50.2911	0.7297

In figure 3, the AES Depth Profile of ZnS/CdTe/HgCdTe, the ratio of Cd and Te components is 1:1.

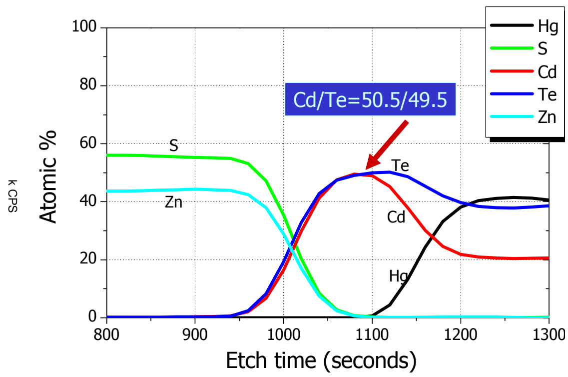

Fig. 3 AES Depth Profile of a ZnS/CdTe/HgCdTe

A new diode with CdTe passivation layer is developed and its photograph is shown in figure 4.

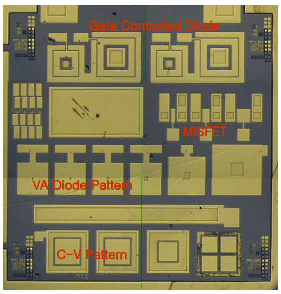

Fig. 4 Photo of a manufactured device.

3.2 Experiment and Results

After making the flip chip a radiation test was performed with the condition as that of sample with ZnS layer. Figure 5 shows the variation of R_o of CdTe with gamma-ray irradiation dose with that of ZnS. With the result we can see that the detector with CdTe passivation layer can sustain its property to the irradiation dose of 1 Mrad.

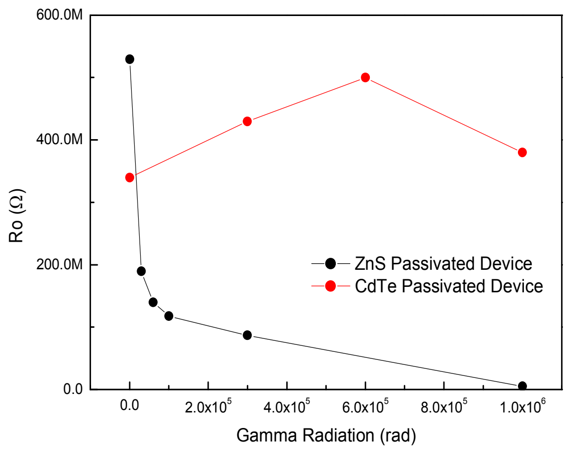

Fig. 5 R_o of devices with Zns and CdTe passivation layer to the Gama-ray dose

4. Conclusion

A study on radiation hardening of infrared(IR) detector, the chief component of IR camera was performed. The radiation test on IR sensor passivated with the ZnS by Co^{60} gamma-ray over 1 Mrads showed the reduction in Ro by 1/100 which was related to the noise level. This effect that was caused by carrier trapping in the ZnS passivation layer increased the leakage current and resulted in degradation in the device performance. For the radiation hardening of IR device we suggested the one with CdTe passivation layer which had a tendency to reluctant to carrier trapping in its layer and developed test patterns. Radiation test to the devices showed that our CdTe passivated device could survived over 1Mrad gamma-ray dose.

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