ELECTRICAL AND DETECTION PROPERTIES OF BULK SEMI-INSULATING GAAS DETECTORS

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1. Introduction

This work is dealing with the study of SI (semi-insulating) GaAs detectors. GaAs is considered as the important candidate for fabrication of semiconductor radiation detectors due to physical parameters of the material and it has been studied for many years [1]. It has been shown that SI GaAs can be suitable for X-ray, γ-ray and charged particle detection [2-3].

In this work we report the results of measurements of current-voltage characteristics of investigated detectors and the analysis of breakdown voltages. Then we analysed their detection performances by using α-particles of 5.49 MeV produced by ^{241}Am. We studied the area size of the collection field (active part) of detector and its dependence on the applied reverse bias.

2. Detectors preparation and experimental methods

The investigated detectors (marked 1-56) were prepared from un-doped semi-insulating GaAs wafer with the thickness of 350 μm and with 2" (50.4 mm) of diameter. The wafer was grown by vertical gradient freeze (VGF) method with (100) crystallographic orientation. The wafer was polished on both sides. Producer was Wafer Technology Ltd, Great Britain. Galvanomagnetic measurements were performed at IEE SAS in Piešťany. The measured resistivity and the electron hole mobility were about of 9.1×10^7 Ωcm and 6285 cm^2/Vs, respectively. These measurements were performed at 300 K. Schottky contacts were prepared on the one part of the substrate. The Schottky contacts of circular shape with various diameters were obtained by high vacuum evaporation using Ti/Pt/Au (10 nm/30 nm/90 nm) metallizations and were created by photolitogaphy using chrome mask. The specific diameters of contacts are 8.0 mm, 6.0 mm, 4.5 mm, 3.2 mm, 2.5 mm, 2.0 mm, 1.4 mm, 1.0 mm, and 0.8 mm. A selected part of these contacts were surrounded by guard rings with 150 μm of width and 50 μm wide gaps between them. However this work is dedicated to the analysis of those detectors without guard rings. A whole area Ni/AuGe/Au (30nm/50 nm/90 nm) metal electrode was formed on the back side of the substrate. A simplified schematic cross-sectional view of one Shottky contact detector is shown in Fig. 1.

Fig. 1: Cross-sectional view of the investigated Schottky contact SI GaAs detector: (a) Ti/Pt/Au Schottky contact (b) bulk SI GaAs (c) Ni/AuGe/Au metal electrode

Fragments of the substrate were glued onto a separate detector support and wire bonded to contacting pad. Current-voltage measurements were carried out with each detector in the dark at temperature of 298 K. Then selected detectors were coupled to a standard spectrometric system, which consisted of charge sensitive preamplifier AMPTEK A250CF, a pulse shaping amplifier ORTEC 572 with semi-gaussian shaping, an analog-to-digital converter Canberra 8701, a multichannel analyzer M2D, and a personal computer. The detectors were supplied with the reverse bias voltage using power supply Canberra model 31060. Alpha spectra of ^{241}Am were measured and active area of detectors was analyzed.

3. Results and experiments

At first we measured current-voltage characteristics of all available detector structures analyzing reverse current flowing through the structures and breakdown voltages. These are very important in term of operation of detector structure. Fig. 2 shows measured reverse current-voltage characteristics for each diameter of circular Schottky contact where a region of detector operation for each of them can be observed. Fig. 3 shows dependence of current density vs. reverse bias for some of the chosen detector structures. The current density values are between 0.5 – 0.8 μA/cm^2.

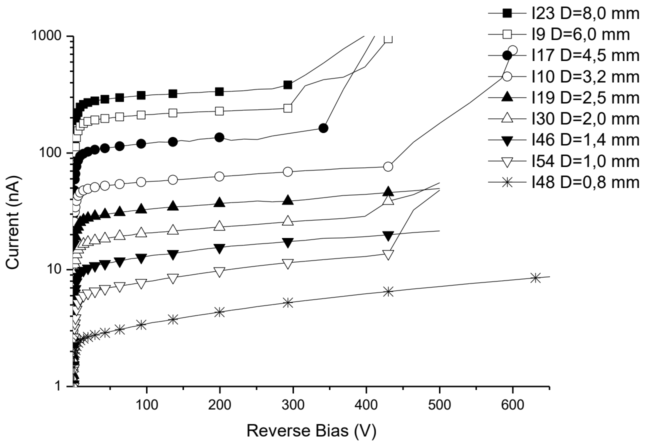

Fig. 2: Measured current-voltage characteristics for each diameter of circular Schottky contact in lin-log scale.

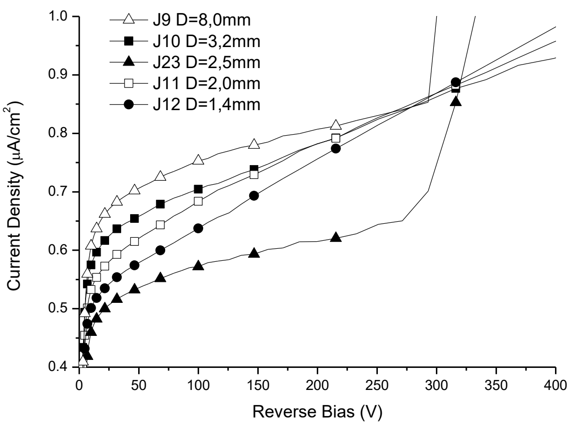

Fig. 3: Dependence of current density vs. reverse bias for selected detectors.

Mean values of breakdown voltage for each contact area are shown in Fig. 4. Detectors equipped with smaller contacts shows higher breakdown voltage than detectors equipped with larger contacts. Mathematical function was constructed that has the best fit to these values as:

$$BV = 581 - 190 * log(A), \qquad (1)$$

where *BV* is the breakdown voltage and *A* is area of the Schottky contact detector.

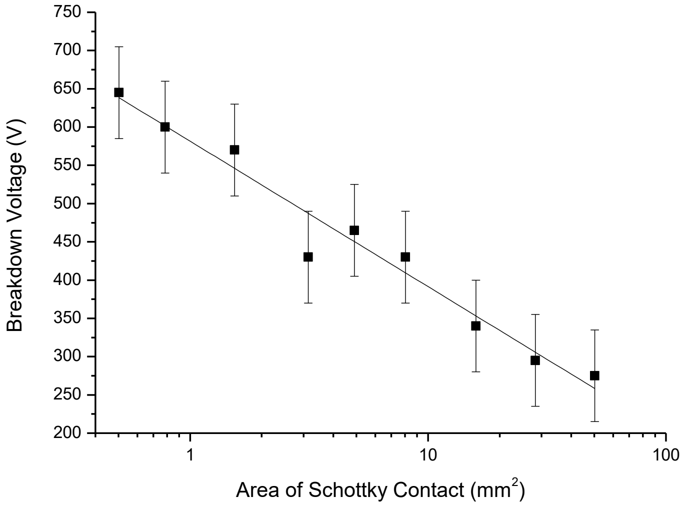

Fig. 4: The dependence of breakdown voltage versus Schottky contact area and the fit approximation in log-lin scale.

Consequently selected detectors were used to detect α-particles of 5.49 MeV energy generated by ^{241}Am source. We analyzed detection performance of four detectors with 2.0 mm, 1.4 mm, 1.0 mm, and 0.8 mm of diameter. We studied the dependence of total counts in photo-peak on mm^2 vs. reverse bias voltage of each detector as shown in Fig. 5. The number of total counts in photo-peak linearly increases with reverse bias of the detector and the peak efficiency is affected by the effective active area of the collection field in the detector. The effective active area of detector is increasing with reverse bias and is slightly larger than Schottky contact metallization area.

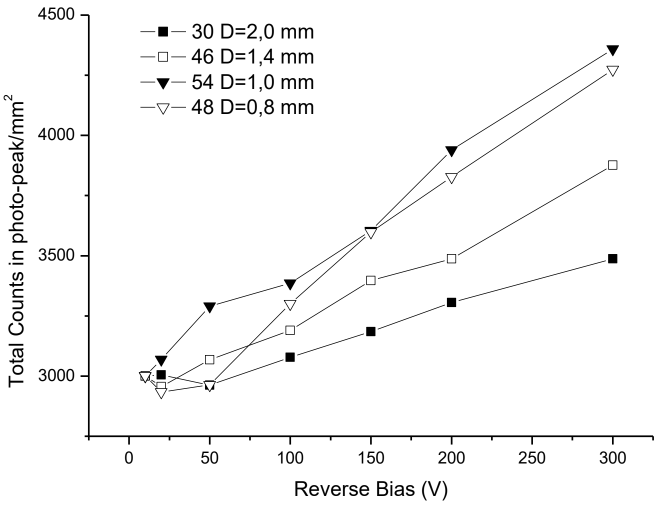

Fig. 5: Measured total counts in photo-peak on mm^2 depending upon reverse bias of selected detectors

The effective diameter of the active area of detector can be calculated from the previous measured data as:

$$D_{active} = \sqrt{\frac{N_V}{N_{10}}} D, \qquad (2)$$

where D_{active} is the diameter of the active area of the detector, N_V is the total count in photo-peak by voltage, N_{10} is the total count in photo-peak at 10 V which can be considered as the reference value for the diameter of the active layer same as the diameter of the Schottky contact. D is the physical diameter of the top Schottky contact. Then the extension Ex of the radius of the active area can be expressed as:

$$Ex = \frac{D_{active} - D}{2} \qquad (3)$$

The dependence of the active area extension versus reverse bias is shown in Fig. 6. We observed the extension of the radius up to 100 μm at 300 V.

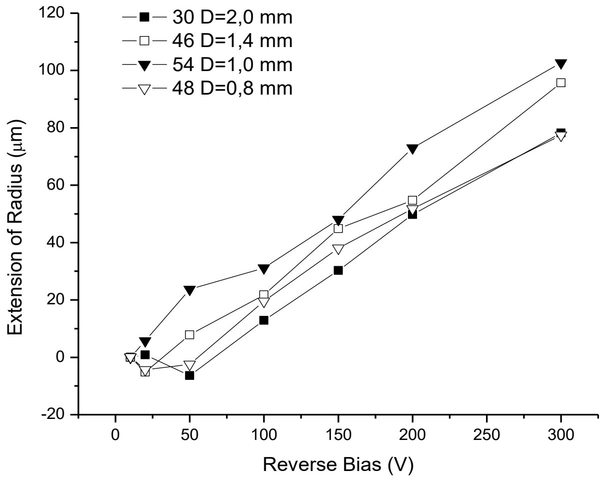

Fig. 6: Dependence of the extension of the radius of the active layer vs. reverse bias of detector

4. Conclusions

We have investigated the current-voltage characteristics and detection performances of SI GaAs detectors with Schottky contacts. First the current-voltage characteristics were analysed and the mathematical function expressing the breakdown voltage of detectors with the size of contacts areas was constructed. The detection performances of selected detectors were studied. We analysed the dependence of extension of radius of the active area vs. reverse bias which linearly increases.

Acknowledgement

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