THE EFFECT OF HIGH-ENERGY ELECTRONS IRRADIATION ON THE CURRENT-VOLTAGE CHARACTERISTICS OF SCHOTTKY BARRIERS DETECTORS BASED ON SEMI-INSULATING GAAS

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1. Introduction

We have studied detectors base on semi-insulating (SI) GaAs many years and we showed their characteristics and potential of using in detection of ionizing radiation [1-3]. The investigation of detector degradation under various type of radiation is also important. In past works we studied behaviour of detectors after (1 MeV) gamma and (1 MeV) neutron irradiations [4-6]. Nowadays we concentrate on degradation of detectors under high-energy (5 MeV) electrons irradiation. High-energy electrons are able to produce point defects like vacancies, anti-sites and interstitials in lattice, which are electrically active and can change the Fermi level and also the lifetime of free carriers.

In this work we report the study of electrical properties of irradiated samples base on SI GaAs Schottky diodes with high-energy electrons. We report the influence of irradiation dose to breakdown voltage and reverse current of detector structure because these parameters are important in light of spectrometric performances of detectors.

2. Detectors preparation and experimental methods

Samples were prepared from the bulk un-doped SI GaAs 2” wafer grown by vertical gradient freeze (VGF) method (producer CMK Ltd., Žarnovica, Slovakia) with (100) crystallographic orientation and dislocation density less than 5000 cm^{-2}. The wafer was polished by the producer from both sides down to (230 ±5) μm and cut into pieces with size about 8 × 8 mm^2. At first galvanomagnetic measurements were performed at each sample. The average measured electron Hall mobility and resistivity were 7150 cm^2/Vs and 1.96 × 10^7 Ωcm. A group of four Schottky contacts was prepared on each fragment of the substrate. The Schottky contacts of circular shape with about 1 mm of diameter were created under high vacuum using Ti/Pt/Au (10 nm/35 nm/90 nm) metallizations. A whole area Ni/AuGe/Au (30 nm/50 nm/90 nm) quasi-ohmic metal electrode was formed on the back side of the substrate. Each fragment of the substrate with four Schottky detectors was 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. Following detectors were placed on a 1 cm thick Al board and were irradiated from Schottky contact side by a pulse beam (3.5 μm pulse duration) of 5 MeV electrons at room temperature using a linear accelerator UELR 5-1S. The distance between the Al board surface and the accelerator exit window foil was 95 cm. The scanning beam width was set to 40 cm and the beam scanning frequency to 0.25 Hz during irradiation. The beam repetition rate was the parameter influencing the dose rate and was set to 10, 20 or 40 Hz, obtaining the dose rate of 20, 40 or

80 kGy/h, respectively. Samples were irradiated in 10 steps using various partial doses (from 1 kGy to 16 kGy) with total dose up to 88 kGy. Table 1 shows partial and total doses after each irradiation step. We utilized 3 samples labeled as 4A, 5A and 6A with 4 Schottky contact detectors and each sample was irradiated using dose rates of 20 kGy/h, 40 kGy/h and 80 kGy/h, respectively.

Tab. 1. *The partial doses applied to detector samples and the total calculated dose in kGy*

Irradiation step	1^{st}	2^{nd}	3^{rd}	4^{th}	5^{th}	6^{th}	7^{th}	8^{th}	9^{th}	10^{th}
Partial dose (kGy)	1	1	2	4	8	8	16	16	16	16
Total dose (kGy)	1	2	4	8	16	24	40	56	72	88

3. Results and experiments

The current-voltage characteristic of each detector structure was measured and breakdown voltage and reverse current flowing through the structure was analyzed. These parameters are very important in term of operation of detector structure. At first we measured current-voltage characteristics of all (22) available detector structures for statistical analysis. Fig. 1 shows distribution of breakdown voltage and reverse current of measured samples. Mean value of breakdown voltage is (295 ± 18) V. The typical reverse current flowing through detector structure between reverse biases from 100 V up to 250 V is rising from a value of about 25 nA up to 33 nA. Mean square deviation is about 10 % of reverse current average value.

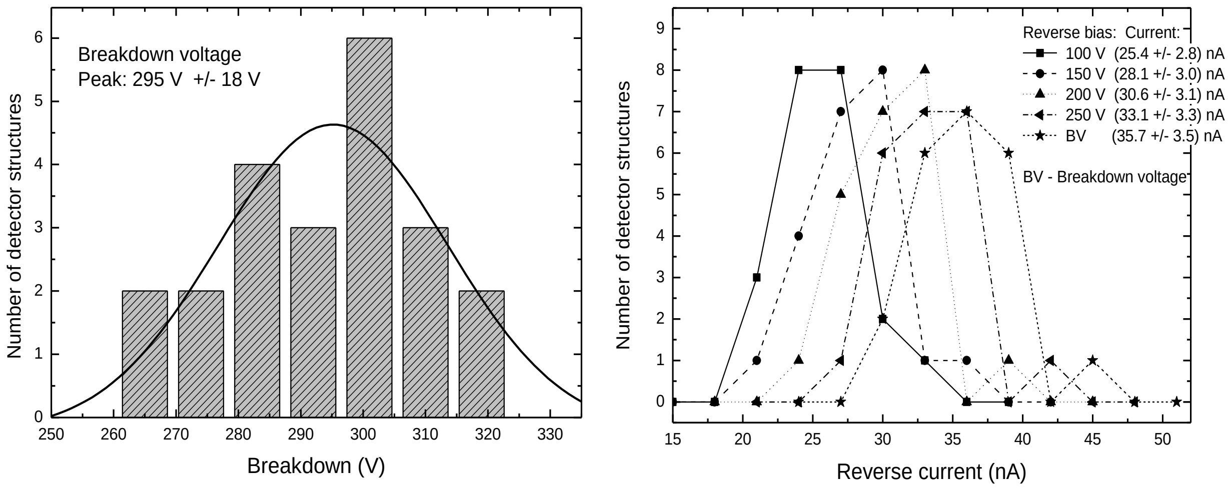

Fig.1: *Distribution of breakdown voltage and reverse current of tested detector structures.*

Detector structures were irradiated by 5 MeV electrons up to dose of 88 kGy. The dependence of breakdown voltage upon total irradiation dose is depicted in Fig. 2. Irradiation dose below 10 kGy slightly increasing breakdown voltage in case of dose rates 20 and 40 kGy/h. The highest dose rate has not positive influence to increasing breakdown voltage. Subsequent rising of total dose results in decreasing of breakdown voltage and higher dose rate more degrades detector structures for total doses up to about 60 kGy. But at highest realized total dose of 88 kGy the influence of dose rate is diminished and the breakdown voltage is decreased to values from 75 % to 79 % of initial value (295 V). Results shows that dose rate has important influence for detector structures only for total dose about 60 kGy and afterward its influence is less distinguished.

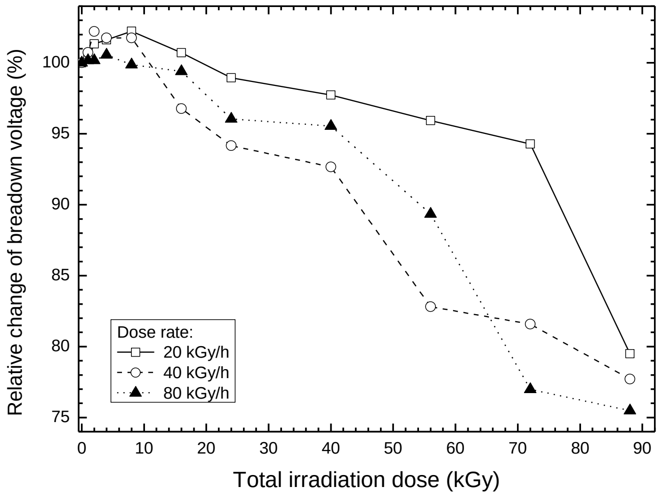

Fig.2: *The influence of reverse bias of detector structures vs. total irradiation dose for three different dose rates (20. 40, and 80 kGy/h).*

The influence of reverse current in dependence of total irradiation dose was also analyzed. Fig. 3 shows relative change of reverse current at 250 V and 150 V on total irradiation dose. At dose rates 20 and 40 kGy/h the relative change or reverse current is mostly identical. The highest dose rate 80 kGy/h more decreases the reverse current. The dependences are similar to breakdown voltage behaviour. Small current rising was observed after irradiation dose of 1 kGy excepting the case of the highest dose rate. Following irradiation dose reduced reverse current. Defects generated by high-energy electrons reduces the breakdown voltage of fabricated structures. Lowering the reverse current indicates that life time of free charge carriers is shortened. Galvanomagnetic measurements (electron Hall mobility and resistivity) of substrate were also analyzed and are published elsewhere [7]. Obtained results indicate that if observed trends of degradation will be continue than fabricated detector structures should be able to operate up to high-energy electron dose of 250 kGy. Further study and increasing of total irradiation dose of electron will be proceeding till detector structures will be capable of operation.

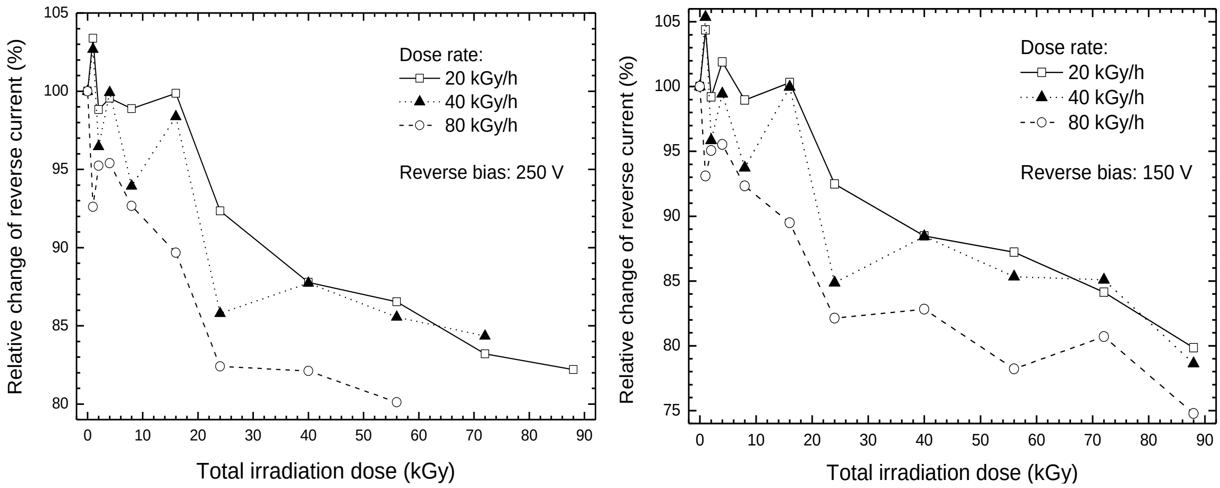

Fig.3: *The influence of reverse current of detector structures vs. total irradiation dose for three different dose rates (20, 40, and 80 kGy/h) and two reverse biases 250 and 150 V.*

4. Conclusions

We have investigated the influence of irradiation with 5 MeV electrons on reverse current-voltage characteristics of SI GaAs Schottky detector diodes. The total irradiation dose of 88 kGy was cumulated in 10 steps whereby after each the breakdown voltage and reverse current were analyzed. Samples were divided into three groups according to different dose rate (20, 40 and 80 kGy/h) which was studied. Results demonstrate progressive degradation and at total dose of 88 kGy the breakdown voltage decreased about 20 – 25 % of value measured on untouched samples according to used dose rate. Very similar dependence was observed also for reverse current flowing through detector structures. This behaviour can be assigned to creation of point defects like vacancies, anti-sites, and interstitials after irradiation with high-energy electrons. Experiments will be continuing until samples are capable of operation.

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