INFLUENCE OF ELECTRON IRRADIATION ON ELECTRICAL PROPERTIES OF GaAs DETECTORS

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1. Introduction

Radiation resistance of semiconductor devices has recently demanded the attention of researches.Here,among all types of ionizing radiation, also the high-energy electrons play an important role, particularly for space applications. The electronics in the spacecraft is exposed to electrons with energies of a few MeV and up to fluencesof 10^{10} cm^{-2}day^{-1}sr^{-1} [1].There are very few studies dealing only with radiation resistance of GaAs detectors against high-energy electrons [2]. In our previous research we have studied the radiation hardness of GaAs detectors against gamma rays and neutrons. Later, we have extended the hardness studies also to high-energy electrons [3]. In this paper we discuss the influence of electron irradiation on electrical properties of GaAs detectors. Both, the forward and the reverse current-voltage characteristics were measured and evaluated regarding parameters important for proper detector function.

2. Detector characteristics

The detectors were prepared from a bulk LEC (Liquid Encapsulated Czochralski) substrate of SI (Semi Insulating) GaAs. The measured resistivity was about $1.1\times10^{8}\Omega$cm and the Hall mobility 5280 cm^2/Vs at room temperature (RT). The wafer was polished from both sides to a thickness of 270 μm. The Schottky electrode, a 120 nm thick AuZn metallization, was evaporated onto the top side using photolithographic masking. The multi-pixel Schottky electrode consists of 8×3 large pixels (400×400 μm^2) connected with 7×2 small pixels (200×200 μm^2). It covers an area of 4.6×1.6 mm^2. A quasi-ohmic metal electrode of the same area was formed by evaporating an eutectic AuGeNi alloy (120 nm) symmetrically on the back side of the substrate.

3. Irradiation

The SI GaAs detectors were irradiated at RT from the Schottky contact side of the device with 5 MeV electrons using a linear accelerator UELR 5-1S.The detectors were fixed on a ceramic support and placed on a 1 cm thick metallic board during irradiation. The distance between the board surface and the foil of the accelerator exit window was 56 cm and 96 cm, respectively.The detectors were irradiated by various total doses in the range from 1 to 69 kGy (fluences from 9×10^{6} cm^{-2} to 6×10^{8} cm^{-2}) with two different dose rates:23 kGy/h and 50 kGy/h, respectively. The various partial doses were adjusted by the irradiation timeperiods at particular dose rates. The different dose rateswere obtained changing the beam repetition rate (10 or 20

Hz) at fixed beam scanning width (40 cm) and beam scanning frequency (0.25 Hz) and by changing the distance between the sample and the accelerator exit window.The detector surface doseswere measured using B3 radiochromic films witha diameter of 1 cm evaluated by Spectrophotometer GENESYS20. Verification of the dose delivered to detector was performed with RISO polystyrene calorimeters.

4. Results and discussion

The SI GaAs with a Schottky barrier acts as a detector of ionizing radiation, when the reverse bias voltage is applied. For this purpose the area of current saturation is optimal, where only negligiblecurrent (nA),in comparison to signal from registered ionizing particle,flows through the detector. The intensity of electric collecting field is increasing withapplied voltageand the charge produced by ionizing radiation will be collected with higher efficiency.On the other hand, the breakdown will make the signal from ionizing particles impossible to detect. The current-voltage (*I-V*) characteristics (Fig. 1) were measured in order to determine the functionality of investigated detectors. The breakdown voltage and the reverse current height were evaluated with respect to the dose absorbed by the detector. The experiments have shown that not only the dose itself but also the doserate influences the properties of GaAs detectors.

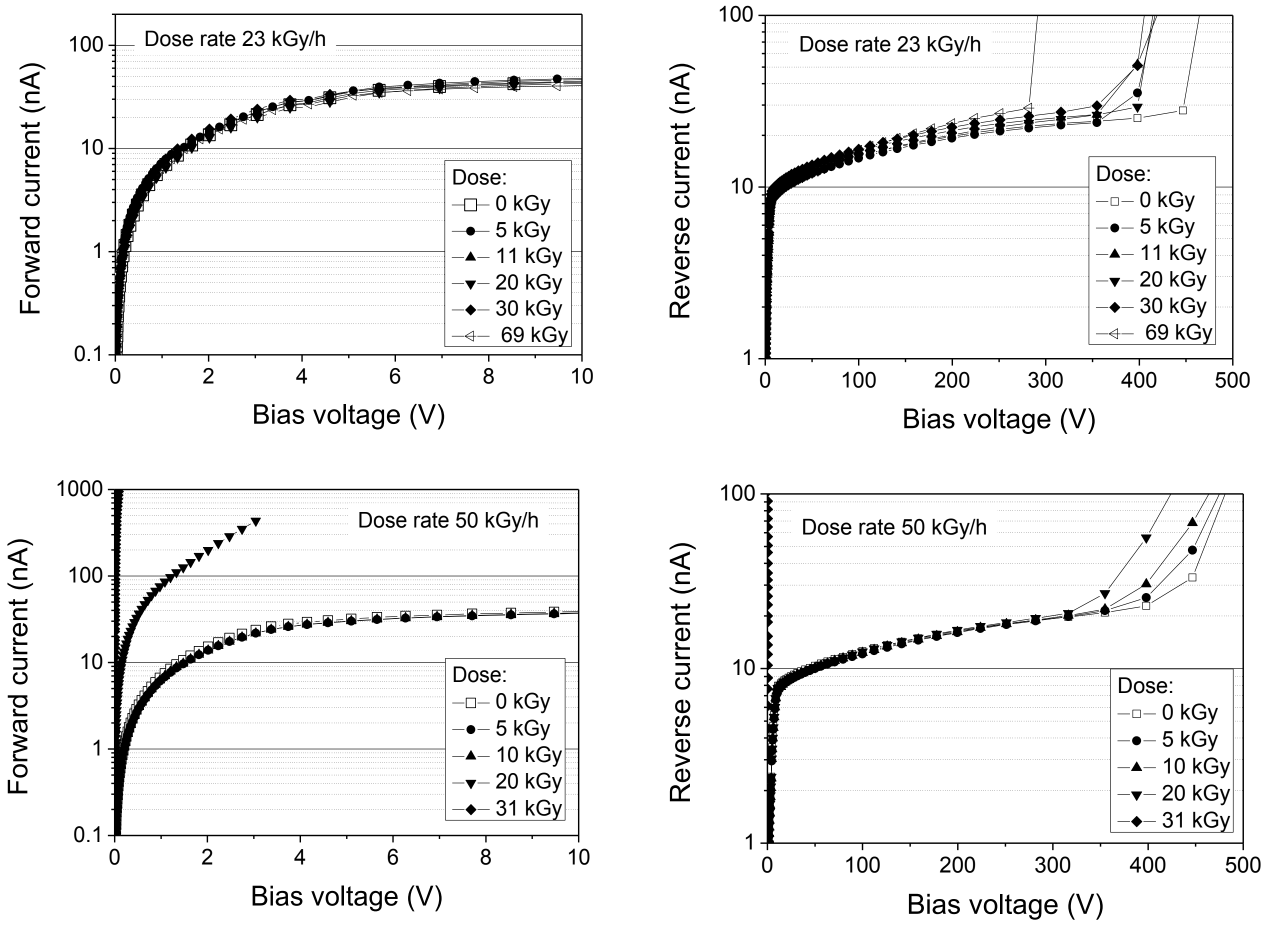

Fig.1: *The forward and reverse current-voltage characteristics of SI GaAs detectors irradiated by various doses of 5 MeV electrons at 23kGy/h (first row) and 50 kGy/h (second row) dose rate, respectively.*

Fig. 1 shows the forward and reverse bias *I-V* characteristics of GaAs detectors at various doses. In the first row there are characteristics of detectors irradiated with lower dose rate (23 kGy/h) and up to higher total dose (69 kGy). In the second row, the characteristics of detectors irradiated by higher dose rate(50 kGy/h), up to a dose of 31 kGy are shown. The forward current in GaAs does not exhibit significant changes at lower dose rate up to a maximum applied dose, but in the case of higher dose rate a significant increase since 20 kGy can be observed. In the case of reverse *I-V* characteristics, a slight change in saturation current and marked changes in breakdown voltage can be seen. These changes are depicted in more detailed and for more investigated samples in Figs. 2 and 3.

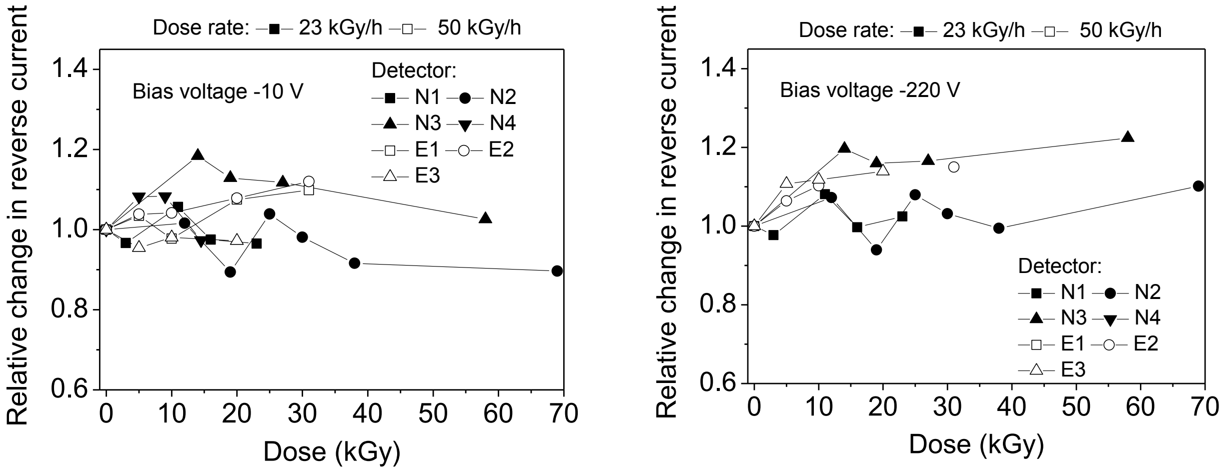

Fig.2:*The relative change of reverse current of SI GaAs detectorsas a function of absorbed dose at various reverse bias voltages.*

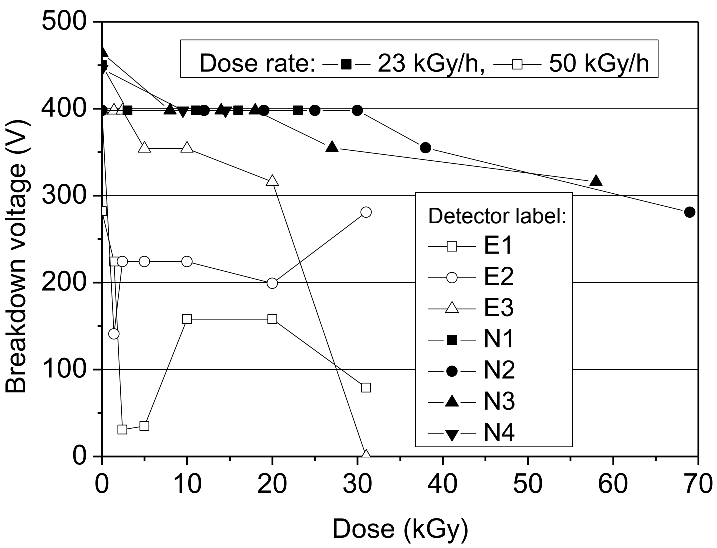

Fig.3:*The breakdown voltage of SI GaAs detectorsirradiated by various doses of 5 MeV electrons at 23kGy/h and 50 kGy/h dose rate, respectively.*

The relative changes in the reverse current with total dose are depicted in Fig. 2 for lower voltage area (represented by -10 V) and for higher voltage area (represented by -220 V), for lower (full symbols) and for higher (empty symbols) dose rates.In the lower voltage area, the influence of total absorbed dose is minimal for both dose rates. The reverse current oscillates around the same value, indicating small changes in the detector properties.In the higher voltage area, the reverse current increase with absorbed dose can be observed, especially at high dose rate and higher doses of low dose rate. It might be caused by the electric charges from additional energy levels in the band-gap created by irradiation. The higher voltage area is important as the detector operating region and such effects will negatively affect the spectrometric and detection properties of investigated detectors.

The influence of the dose and the dose rate on the detector breakdown voltage is shown in Fig. 3. The maximum detector operating voltage in the reverse direction before irradiation was in the range from 280 to 475 V. After irradiation by 23 kGy/h dose rate, it shows an initial decrease (except detector N2) and stays constant up to a dose ranging from 20 to 30 kGy, dropping for higher doses (down to 281 V at 69 kGy). A significant initial decrease in breakdown voltage followed by increase and slight drop up to a dose of 20 kGywas observed with majority of the samples irradiated by 50 kGy/h dose rate. The detector labeled E3 shows continual decrease in breakdown voltage down to detector destroy at 31 kGy.The decrease of the detector breakdown voltage with the dose indicates a change in the electrical properties of the Schottky contact interface. Irradiation might have introduced defects in the Schottky barrier leading to a decrease of its height followed by reduction of the maximum applied reverse bias voltage, which is in accordance with the results concerning reverse current.

5. Conclusion

Two series of SI GaAs detectors were irradiated by 5 MeV electrons at different dose rates. It was shown; that the dose rate has an important influence on the electrical properties related to proper detector function. Higher dose rate degrades the electrical parameters at lower total doses. Similar effect was observed also with pulsed irradiation but using 14 MeV neutrons [4]. For low pulsed frequency they [4] expect that annealing between pulses may result in a significantly decreased rate of damage accumulation. On the other hand, high fluxes in the pulses may limit recombination, therefore leading to fast rates of damage accumulation even at elevated temperatures. Also in our case,the pulsed irradiation wasused. Different pulse frequencies set as different beam repetition rates were used to vary the dose rate.

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