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Semi-insulating GaAs detectors degraded by 8 MeV electrons up to 1500 kGy

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We have dealt with SI (semi-insulating) GaAs detectors for two decades and successfully developed GaAs detectors for gamma and alfa spectrometry as well as for neutron detection [1, 2]. We have also fabricated GaAs sensor chips which were successfully applied to a TIMEPIX readout chip for radiation imaging [3]. Our radiation hardness studies included the resistance of GaAs detectors against gamma rays, fast neutrons or electrons [4]. Results of these studies suggest that the degradation is manifested by the generation of defects in GaAs lattice (e.g. vacancies and interstitials) acting as traps for charge carriers, which shortens their lifetime and decreases their mobility. The shorter carrier lifetime will lead to higher detector resistivity shifting the breakdown voltage higher. On the other hand, the charge collection efficiency will be degraded due to trapping. These processes were observed in our previous experiments [5].

In this paper, we have involved positron annihilation spectroscopy (PAS) aimed at characterization of the vacancy-type defect production in the GaAs-substrate irradiated by 8 MeV electron up to doses of 1500 kGy. Radiation-induced mono-vacancies were clearly identified in the irradiated materials, and their concentration was estimated by the standard trapping model [6]. The results show an onset of radiation degradation below 500 kGy, followed by a linear increase in the concentration of vacancies. The effect of these vacancies on the detector quality was studied by galvano-magnetic measurements utilized to determine the electron Hall mobility and the resistivity of the SI GaAs substrate. An increase of the material resistivity and decrease of charge mobility were observed with increasing applied dose. On the contrary to our previous studies, the detector material was degraded before contact evaporation, which ensured separation of radiation degradation solely to the bulk material, excluding the contact degradation. After the evaporation of Schottky contacts, the current-voltage characteristics of the structures were measured (Figure 1). With an increasing dose, one could observe an increase of the reverse current in the voltage range up to 450 V, the reduction of the barrier height of the Schottky contact almost totally disappearing at a dose of 1 MGy (the current almost linearly increases with the reverse bias without any saturation) as well as vanishing of the breakdown behaviour beneath 500 V with all doses applied. The 241-Am gamma and alfa spectra were analysed to determine the spectrometric quality of the detector after degradation. A gradual decrease of charge collection efficiency was observed with increasing dose.

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