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GaAs radiation-degraded detectors: gamma spectrometry at lowered temperatures

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Semi-insulating (SI) GaAs is a wide band gap (1.42 eV) semiconductor material suitable for preparation of detectors of ionizing radiation operating at room temperature. The radiation hardness, which affects detector lifetime, has been studied utilizing degradation by various types of radiation. It was shown that GaAs detectors are radiation hard against a few MGy of high-energy (MeV) electrons. The main reason of detector functionality degradation was the reduction of charge collection efficiency (CCE) together with reverse current increase, raising the total noise of detector. Both factors lead to drop of the signal to noise ratio (S/N) down to close to 1 disabling detector functionality. Thus, the measuring ability of degraded detector depends on how large signal the registered radiation creates [1, 2] and less ionizing particles, like keV gamma rays, might not be detectable with degraded detector.

In this paper we improve the ability of SI GaAs detectors degraded by 5-8 MeV electrons to measure the gamma spectra of 30 –80 keV photons by reducing the noise level in spectra by cooling the detector. It might have interesting outcomes for SI GaAs detector limits in space applications.

First, the current-voltage characteristics were measured during detector degradation (Fig. 1). An increase of reverse current in typical detector operating region of 150 –300 V reverse bias can be observed with increasing dose, which was accompanied with vanishing of the current saturation. After 1000 kGy the current almost linearly increases with reverse bias and the detector exhibits ohmic-like behavior. The reverse current increases from 7 to 85 nA at 200 V reverse bias after degradation by 1500 kGy dose and the signal from gamma spectra disappears in the noise [2]. Cooling the detector from room temperature down to 0, -20 and -40C led to gradual decrease of detector reverse current (Fig. 2). The reverse current of the same degraded detector was reduced to 38 pA after detector cooling to -40C at 200 V reverse bias, which improved its spectrometric ability. Moreover, the cooling of detector increases its breakdown voltage, which enables using the higher operating voltage, leading to higher CCE and better detector spectrometric abilities. The cooling effect on gamma spectrometry of various types of SI GaAs detectors degraded by high energy electrons will be compared.

[1] Šagátová, A. Zaťko, B., et al., AIP Conference Proceedings 2411 (2021), 080013.
[2] Šagátová, A., et al., Materials Today: Proceedings 53 (2022) 293–298.

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