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Improved spectrometry of semi-insulating GaAs detectors by significant thinning detector thickness

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The semi-insulating (SI) bulk GaAs has been studied as a material for semiconductor detectors operating at room temperature for decades, exhibiting good gamma and X-ray detection efficiency and stability during its operation. Moreover, its high carrier mobilities up to 8000 and 400 cm2V−1s−1 for electrons and holes, respectively at room temperature ensure high counting rate of SI GaAs detectors. Furthermore, their confirmed high radiation hardness predetermines their use in harsh environment or for long-term operation in space applications. However, in comparison to traditional semiconductor detectors based on silicon, the bulk SI GaAs detectors suffer from worse spectrometric properties like charge collection efficiency (CCE) or energy resolution. These parameters are affected by the base material quality and the intensity of electric collecting field in the detector volume, which is controlled by the applied bias and detector electrodes. It has been shown, that the CCE increases with the applied bias, but it saturates to the certain value depending on the GaAs detector thickness. A thicker detector achieves a lower maximum CCE and vice versa, for both, the alpha and gamma spectrometry [1]. In the case of bulk undoped SI GaAs detectors, we have achieved the highest CCE of about 80% for 230 μm thick Schottky barrier type detectors.
Reducing the substrate thickness while preserving the area of detector will improve the spectrometric properties. However, the GaAs substrate preparation technology prevents the production of SI GaAs wafer thinner than 200 μm, mainly due to its fragility.
At the Institute of Electrical Engineering, SAS in Bratislava, the technology of preparing SI GaAs detectors with a thickness in the range from 60 um up to 200 um was developed, using the wet chemical etching method. The prepared detectors have circle Schottky electrode of 0.5 mm in diameter on the top side based on Ti/Pt/Au metallization and the full area Ni/AuGe/Au ohmic electrode on the etched bottom substrate. First, the current-voltage characteristics of prepared detectors were measured, showing saturation current in the range of a few nA. Then, the prepared detectors were tested with triple 239Pu238Pu244Cm alpha particle source in vacuum to determine their CCE and energy resolution. The spectrometric chain based of Cremat charge sensitive preamplifier and a Caen Hexagon digital pulse shape amplifier was utilized. The best achieved energy resolution was about 80 keV @ 5.5 MeV alpha particles obtained with the thinnest (60 um) SI GaAs detector, which reached also the best CCE of 91% saturating at bias higher than 45 V. The detectors with such improved CCE enabled to experimentally determine the lifetime of electrons in SI GaAs and thus characterize its quality.

[1] A. Sagatova et al. EPJ Web of Conferences 288, 10013 (2023)

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