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Experimental analysis of the electric field distribution in GaAs radiation detectors

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Abstract

We describe the results of experimental studies of Liquid Encapsulated Czochralski (LEC) semi-insulating GaAs detectors with different contact areas. The detector active area spreading at different applied bias is proven by three various experiments. In the first, the scan of the detector electrode and adjacent area was performed using the 660 nm pulsed laser beam, with a spot diameter of 50 μm. The other experiments use the spectra measured by tested detectors, when irradiated by ^{241}Am α source (5.48 MeV). The experiments show relation between bias voltage applied and the range of active detector area from the edge of the detector contact.

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Keywords: GaAs radiation detector; Electric field spreading; α detection; Laser scan

1. Introduction

Digital radiography has achieved a great progress during last decade, especially because of the significant improvement of properties of position sensitive semiconductor radiation detectors. The detection unit of imaging system is usually realized by tight arrangement of detection units created by blocking contacts on common semiconductor wafer. This arrangement could cause the so-called "cross-talk" of the units, which deteriorates the spatial resolution of the whole device. The knowledge of the lateral distribution of the electric collecting field of single detector units will be helpful for the contact arrangement design.

Moreover, the lateral field enlargement beyond the electrode edges was indicated by our previous experiments with semi-insulating (SI) GaAs structures [1]. A cumulative increase of the detected counts per unit of a segment contact area (detection efficiency) with increasing bias voltage applied was observed, which is one of the most important parameters of the detector unit. The detection efficiency evidently grows while the contact area decreases. This result can be explained by the enlargement of the detector active volume beyond the detector contact edges. This effect is more pronounced with smaller contact areas, because the smaller electrodes have more significant peripheral contribution than the large electrodes. The enlargement of the detector electric field was already studied via scanning the detector surface with 2 MeV proton beam in Ref. [2], where the signal was collected up to 500 μm distance from contact border of the 200 μm pixel SI GaAs diode. In Ref. [3] they observed the signal in 200 μm distance when 1 mm pad of SI GaAs detector was scanned by ~1000 nm laser light. We decided to study this phenomenon in detail using the laser scan of the detector surface in order to obtain the relation between the enlargement and bias voltage applied. The obtained results are furthermore proven by the α spectra measurements.

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The detectors under investigation were prepared from Liquid Encapsulated Czochralski (LEC) SI GaAs substrate manufactured by CMK, Ltd., Žarnovica, Slovakia. The resistivity of GaAs substrate was $6.70 \times 10^7\,\Omega\,\text{cm}$ and the Hall mobility $6441\,\text{cm}^2/\text{V s}$. Wafers were polished down to the thickness of 300 μm. One twenty nanometer thick top Schottky contacts of various square shapes were made of an Au/Zn alloy using optical photolithography (Table 1).

Silicone nitride passivation layer with the thickness of 100 nm was grown by plasma-enhanced chemical vapour deposition technique onto the top-side of the samples. A full area backside ohmic contact was prepared by vacuum evaporation of an Au/Ge/Ni eutectic alloy.

2. Laser scan of detector surface

The assumed detector active area spreading with the increasing bias voltage applied is proven by scanning the electrode and the adjacent area of detector using the 660 nm pulsed laser beam, with a spot diameter of 50 μm controlled by a micro-shift device with precision of 2 μm.

Table 1
Top detector contact dimensions defining the size of pixel

Detector label	Pixel dimensions (μm)	Area (mm^2)
D1	1840 × 1840	3.386
D2	1840 × 840	1.546
D3	840 × 840	0.706
D4	500 × 500	0.250
D5	360 × 360	0.130
D6	230 × 230	0.053

The GaAs detectors with top contact of a square shape with the sizes of 230, 360 and 500 μm respectively, were chosen for this experiment. The top contact and adjacent area of the detector were illuminated by 50 μm spot of red laser light in steps of 50 μm. The detector signal obtained at each step was amplified by fast preamplifier PHILIPS (~mV) and an average of 1000 values was recorded depending on the laser position over the detector surface using the fast digital oscilloscope (LeCroy WavePro, 1 GHz bandwidth). Pictures obtained by different pixel detectors at various bias voltages applied on them (−100, −200, −300 V) are depicted in Fig. 1. It can be clearly seen that the pixels were not placed perpendicularly with the pixel edge to the direction of scanning. The black square in the middle of figure represents the pixel of top contact, which does not transmit the red light. The light area around represents how far the electric collecting field reaches. One can also observe, that the signal (corresponding to electric field intensity) was the highest at −300 V and the lowest at −100 V applied by all three detectors. In figures obtained at −200 V the real shapes of pixels are outlined across them. It proves, that the electric field of detector spreads beyond the detector contact edges and with the increasing bias voltage applied it is spread into distance. One more thing should be noticed in Fig. 1. The distance in which the signal spreads from the side of the detector pixel is approximately the same at one bias voltage applied within all sizes of

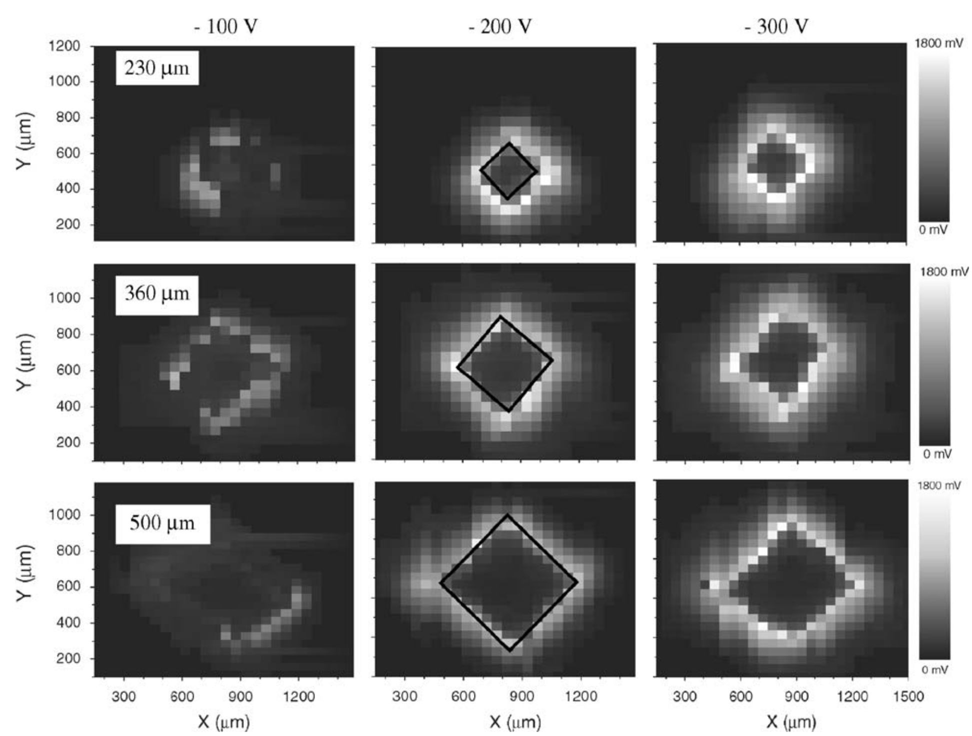

Fig. 1. Single pixel detectors with square size 230, 360 and 500 μm scanned by red laser at various bias voltages applied (−100, −200 and −300 V). The dark area in the center represents the non-transparent pixel contact.