SEMI-INSULATING GAAS DETECTORS OF FAST NEUTRONS

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1. Introduction

Recently, detectors of neutrons are essential part of many fields of science and research like: cosmic research, particle physics, radiation safety, material science and nuclear energetics. In the past few years, there has been an increased interest in the development of alternative neutron detection technologies. Semiconductor-based neutron detectors can be included among many promising alternative neutron detection technologies. These detectors are typically small and compact in comparison to conventional gas-filled proportional, scintillation or activation neutron detectors. The semiconductor based neutron detectors exhibit good discrimination ability against gamma radiation, which is often mixed to the neutron radiation and particularly a strong radiation resistance [1].

Semiconductor based detectors of fast neutrons use the principle of neutron conversion through elastic scattering on protons or light nuclei of chosen material in so called conversion layer on the top of the detector [2-5]. Low atomic number material such as hydrogen tend to have relatively high elastic scattering cross sections for fast neutrons, and often (n,p) reactions from fast neutrons interacting in hydrogen-filled materials are used for fast neutron detection. HDPE (high density polyethylene) and PE (polyethylene) have a high concentration of hydrogen, and energetic recoil protons (hydrogen nuclei) scattered by fast neutrons within HDPE/PE material can be detected by a charge-particle detector.

The present work deals with the technology of HDPE neutron conversion layer application on the surface of semi-insulating (SI) GaAs detectors via developed polypropylene (PP) based glue. The influence of glue deposition on the electric properties of the detectors was studied as well as the ability of the detectors to registrate the fast neutrons from ^{239}Pu-Be neutron source.

2. Experimental results and discussion

The detector structures were prepared from bulk VGF (Vertical Gradient Freeze) detector-grade SI GaAs substrate made in CMK Ltd. Slovakia. The resistivity of the material is about 10^7 Ωcm and the Hall mobility of more than 6500 cm^2/Vs at room temperature. The wafer was polished down from both sides to 270 μm. The Schottky electrodes of 120 nm thick AuZn metallization were evaporated onto topside using photolitography masking. The electrode has the shape of 8×3 connected pixels covering the area of 6×3 mm^2. The whole area quasi-ohmic metal electrode was formed by evaporation of eutectic AuGeNi/Au alloy (50/70 nm) on the back side of the substrate.

The technology of the HDPE neutron converter layer application was devised in collaboration with the Polymer Institute of Slovak Academy of Sciences in Bratislava. The HDPE layer had to be fixed at the surface of SI GaAs detector, on its Schottky metallization side. The brittle character of the GaAs substrate prevented from any mechanical fixing of the HDPE layer to the detector. Any potential gap of air between the detector and HDPE layer would distort the spectrum. Moreover, the isolation of the wires leading the signal from the detector have had to be ensured. Therefore the dielectric polypropylene (PP) based glue diluted with toluene (10 % solution) was prepared. Its supple consistence would minimize prospective ruggedness of the detector or HDPE layer, preventing from air gap formation. The polypropylene chemical structure is similar to the HDPE material. It has little lower density of 0.855 g/cm^3 than HDPE 0.960 g/cm^3, on the other hand PP (molecular formula $(C_3H_6)_n$) contains more hydrogen atoms in each molecule than HDPE (molecular formula $(C_2H_4)_n$)). From the point of view of the neutron conversion, the content of the H atoms is critical parameter. The PP glue of a volume of about 10 ml was deposited on the HDPE using micropipette and then fixed on the Schottky electrode side of the GaAs detector.

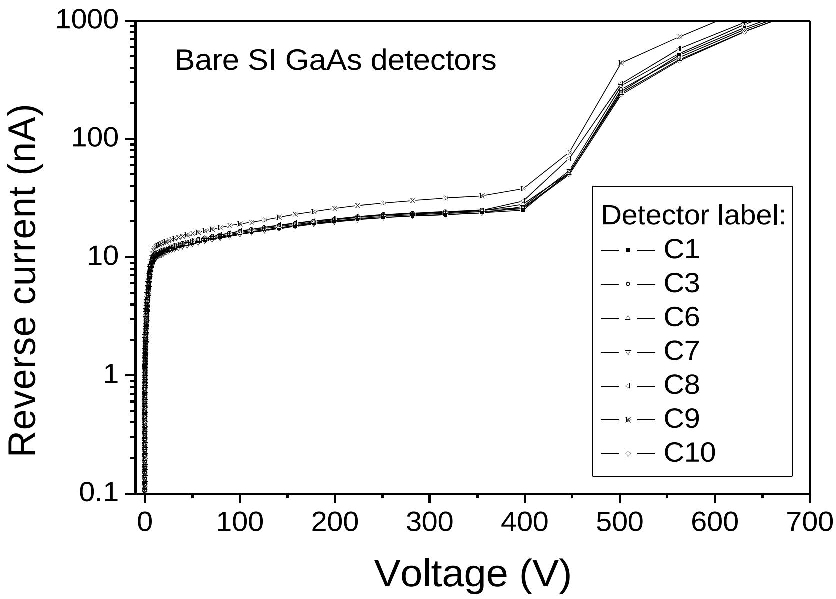

Fig.1: *Measured reverse current-voltage characteristics of the detectors before HDPE layer deposition, at room temperature.*

The current-voltage characteristic for reverse direction was measured for all tested detectors before the glue and HDPE deposition (bare detector Fig. 1.) and after the HDPE application, at room temperature. The electric properties of bare detectors were very similar, the reverse current about 20 nA at -200 V and the breakdown voltage of - 400 V. The application of the HDPE neutron converter layers of various thicknesses (100 – 800 μm) did not degrade the electrical properties. On the contrary, we have observed a slight decrease of the reverse current with all the detectors (Fig. 2). The difference of the reverse current of the bare detector and HDPE coated detector was more significant at higher reverse voltage applied (158 V vs. 350 V in Fig. 3). The breakdown voltage stayed unchanged.

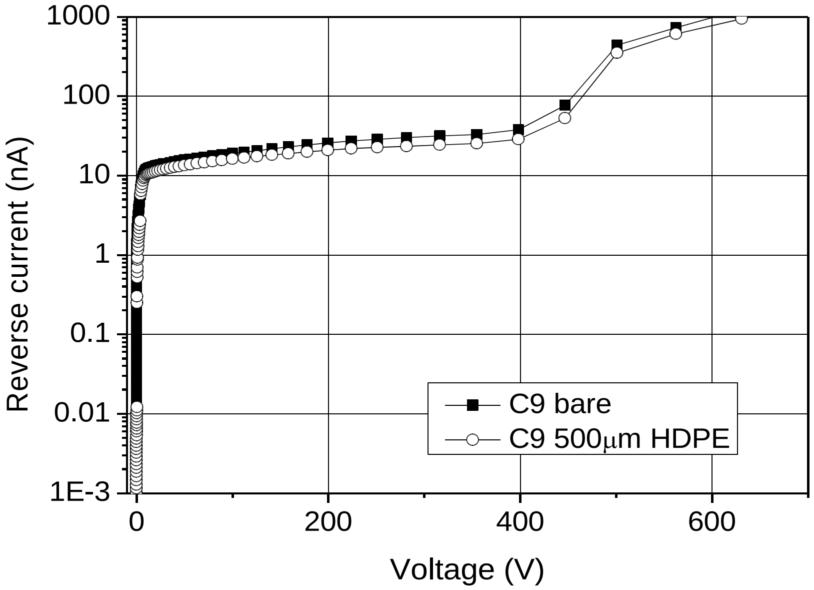

Fig.2: *The measured reverse current-voltage characteristics of the detector with 500 μm HDPE layer: before (black filled square) and after (empty square) application.*

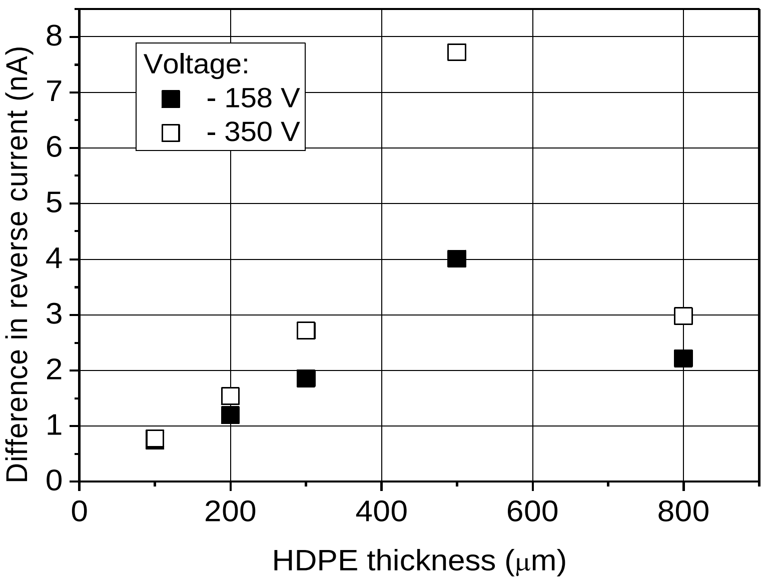

Fig.3: *The difference of the reverse current of the bare detector and the reverse current of the detector with HDPE layer as a function of the layer thickness at voltage of - 158 V and - 350 V respectively.*

The SI GaAs detector with 500 μm HDPE convertor layer was chosen for neutron detection, as according the MCNPX simulations it was determined as the optimum HDPE conversion layer thickness [6]. We used the ^{239}Pu-Be source of fast neutrons with energy up to 12 MeV and the most probable energy of about 4 MeV. The detector was connected to the spectrometric chain based on InSpector2000 readout electronics. The measured pulse high spectra at various voltages are shown in the Fig. 4. The first sharply decreasing part (channels

0- 6) corresponds to the preamplifier and detector noise. The second part (channels 6 – 20) represents gamma ray detection and the third part (channels 20 – 1000) the neutron detection. As the voltage applied increased, the active thickness of the detector enlarges and more proton energy is registered by the detector, which displays in higher channels.

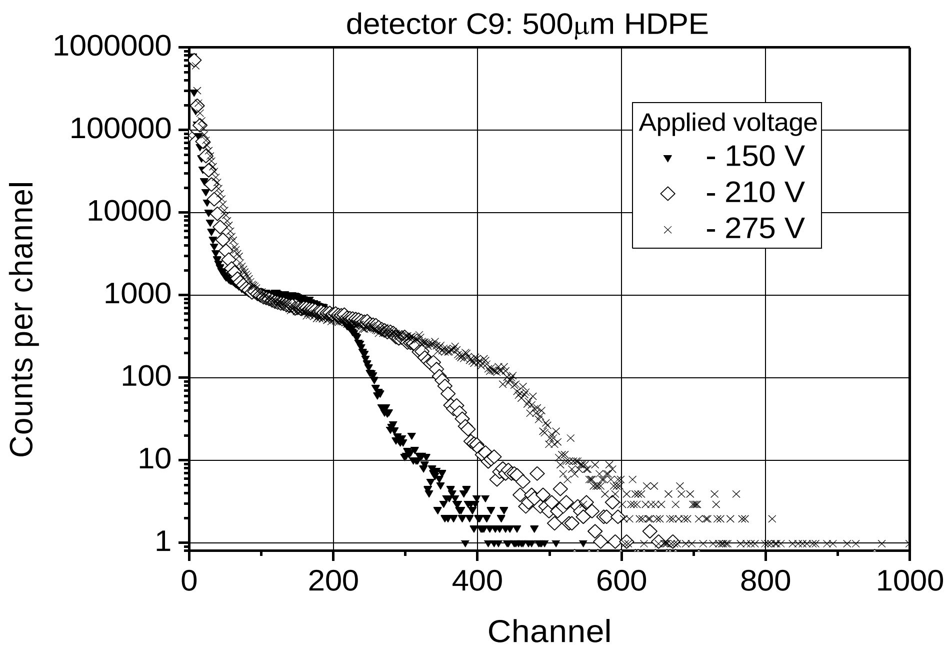

Fig.4: *The spectrum of fast neutrons from ^{239}Pu-Be neutron source measured by SI GaAs detector with 500 µm HDPE convertor layer at various voltage applied.*

3. Conclusions

The technology of the HDPE neutron conversion layer application on the surface of semi-insulating (SI) GaAs detectors via developed polypropylene (PP) based glue was devised and successfully used. The deposition of the glue did not degrade the electric properties of the detectors, contrariwise the reverse current slightly decreased, more distinctly with higher voltage applied. The ability of the detector with 500 µm HDPE to registrate the fast neutrons from ^{239}Pu-Be neutron source was proved.

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