STUDY OF PARTICLE DETECTOR BASED ON SIC EPITAXIAL LAYER

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1. Introduction

Silicon carbide is promising material for radiation-resistant electronics, high-temperature electronics and high-frequency and power devices. The electron saturation drift velocity of 2×10^7 cm/s in the 4H polytype, together with the breakdown voltage of 4×10^6 V/cm, make this material also a very good candidate for a detection medium in particle detectors [1, 2]. The band gap energy of 4H-SiC and the mean energy of electron-hole pair creation are 3.26 eV and 7.78 eV, respectively.

Detectors based on 4H-SiC epitaxial layer can attain a very high spectrometry of X-rays at room and also elevated temperature. Bertuccio *et al.* acquired spectra of ^{241}Am radioisotope and reported the noise energy of 315 eV FWHM (Full Width at Half Maximum) and 797 eV FWHM at 27 °C and 100 °C, respectively [4, 5].

Results obtained by F. H. Ruddy and J. G. Seidel show very good radiation resistance of 4H-SiC detectors. Detectors were exposed to gamma radiation produced by ^{137}Cs with dose up to about 5.5 MGy and no significant deterioration in detection of ^{238}Pu alpha-particles was observed [5].

The present work deals with particle detector based on 4H-SiC high purity epitaxial layer. The response of detector to alpha particles produced by ^{241}Am was studied. The detection of fast neutrons produced by ^{239}Pu-Be was also examined.

2. Experimental results and discussion

Detector structures were prepared from a 105 μm thick nitrogen-doped 4H-SiC layer (with doping of about 1×10^{14} cm^{-3}) grown by the LPE on a fragment of a 3” 4H-SiC wafer (doping level ~2×10^{18} cm^{-3}, thickness 350 μm), by the insertion of a 0.5 μm thick n+-SiC buffer layer with concentration of 1×10^{18} cm^{-3}. The radiation detector was prepared by evaporation of a double layer of Au-Ni/4H-SiC with thickness of 80-40 nm on both sides of the wafer fragment with a high vacuum electron gun apparatus. The Schottky barrier contact with diameter of 1.4 mm was formed on the epitaxial layer through a contact metal mask while full area contact was evaporated on the other side (substrate). No sophisticated topology with a guard ring was used. Close prior to evaporation, the sample was cleaned in boiled acetone and isopropyl alcohol, washed in deionized water and dried by nitrogen flow. The schematic view of detector is depicted in Fig. 1.

The current-voltage characteristics for forward and reverse directions were measured at room temperature and the results are shown in Fig. 2. The detector diode has very high rectifying ratio. In the reverse direction, the current is rising slowly up to about 100 V and further it is steeply increasing. This is probably caused by surface leakage and using a guard ring will be necessary for current decreasing at higher voltages. The current density is extremely low at room temperature, below 1×10^{-10} A/cm^2 at -100 V and measuring of small area samples is very difficult due to current flowing less than 0.1 pA.

The detector was connected to the spectrometric chain and used for detection of alpha particles (5.5 MeV) produced by ^{241}Am radioisotope. The spectra measured at different voltages are depicted in Fig. 3. The peak position shifts to higher energies with voltage rising. The energy resolution or FWHM of measured peak decrease steeply from -10 V to -30 V and stay almost the same up to -150 V and after that the peak is broadening. This behavior corresponds to current-voltage measurement, precisely to dynamic resistance of the structure. The best energy resolution of 58 keV (1.06%) in FWHM was observed at -75 V. The

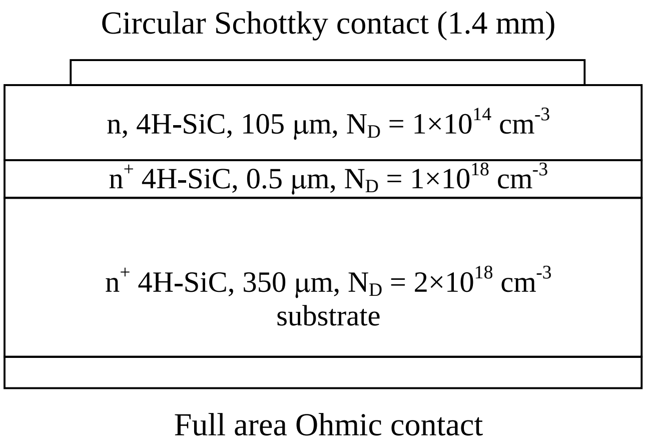

Fig.1: *Schematic cross-section view of SiC particle detector.*

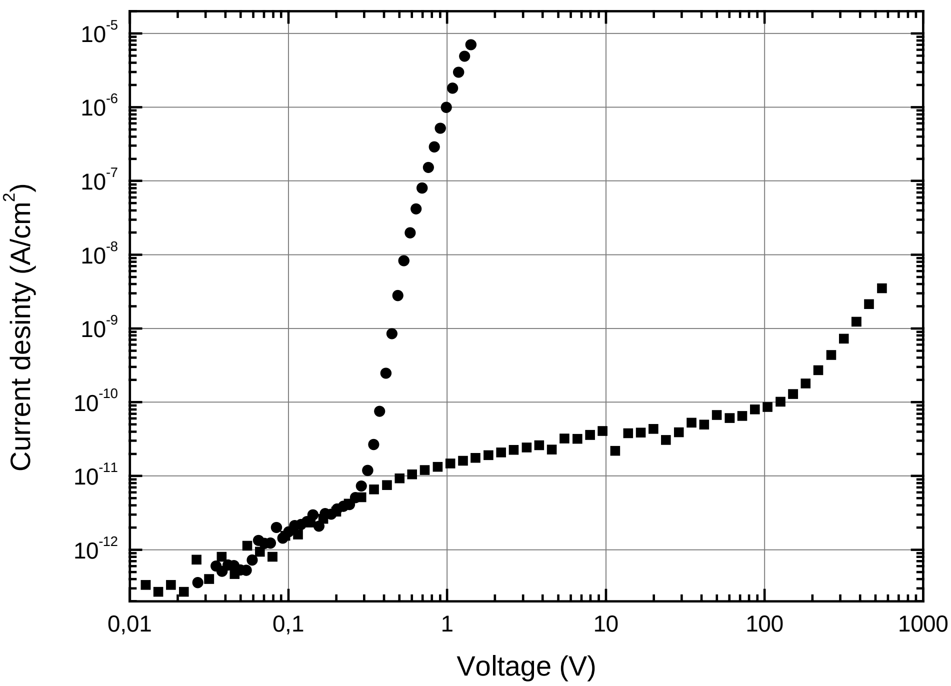

Fig.2: *Measured forward and reverse current-voltage characteristics at room temperature.*

dependence of CCE (Charge Collection Efficiency) vs. reverse bias is depicted in Fig. 4. The detector reaches almost 100% CCE at voltages higher than -150 V.

SiC is able to detect fast neutrons directly because it consists of light atoms like silicon and carbon. Fast neutron can recoil from Si or C and part of its energy will be transferred to Si or C ion. The measured spectrum of fast neutron generated by ^{239}Pu-Be neutron source is depicted in Fig. 5. The silicon in lower channels and carbon-recoil

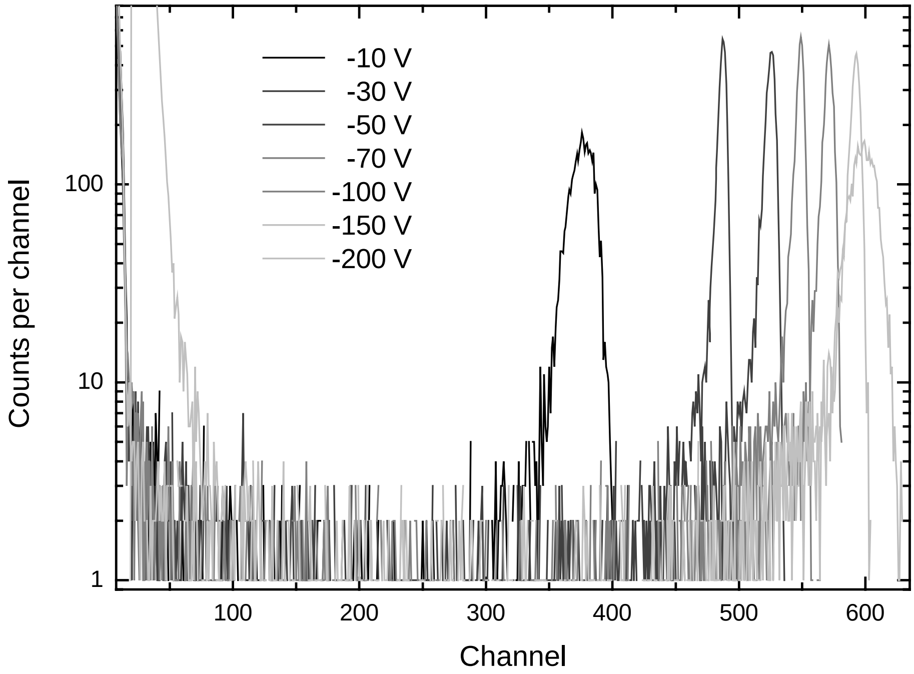

Fig.3: *Measured pulse height spectra of alpha-particles produced by ^{241}Am radioisotope.*

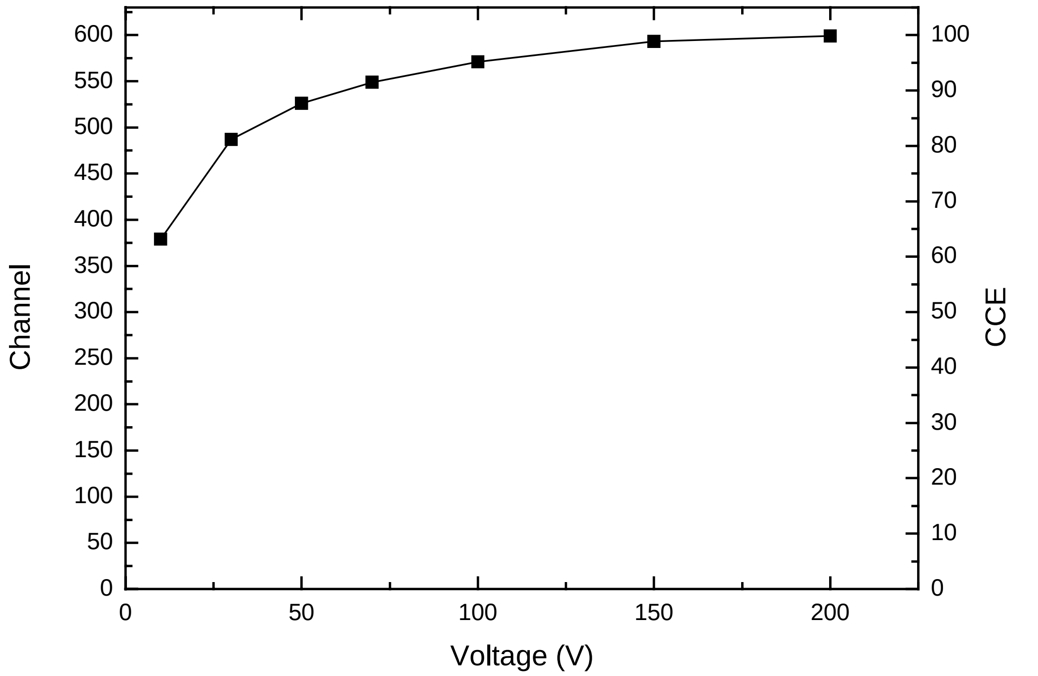

Fig.4: *Calculated CCE vs. reverse bias applied on detector.*

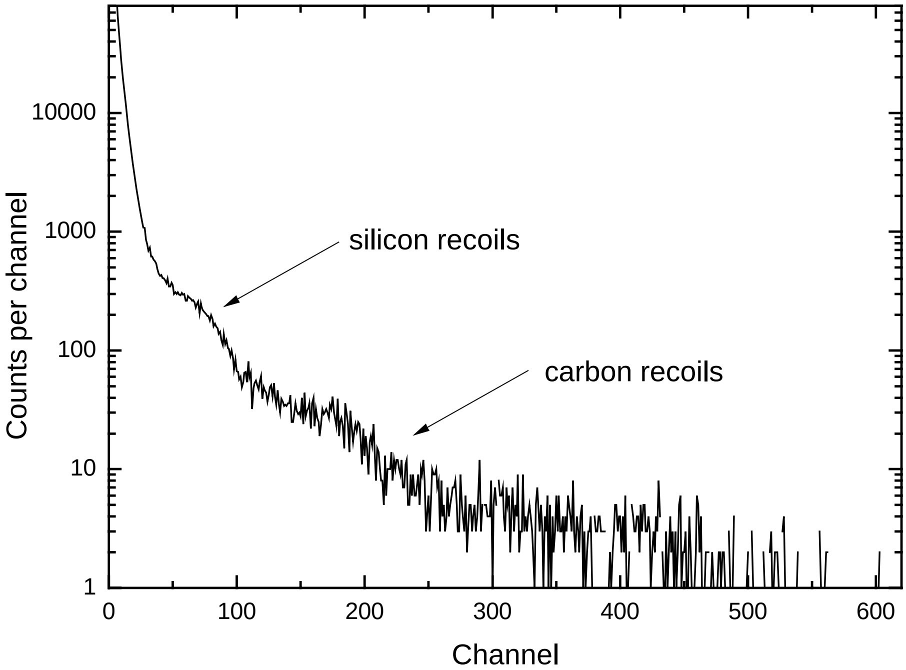

Fig.5: *Measured pulse height spectra of fast neutrons produced by ^{239}Pu-Be radiation source.*

continuum in higher channels can be seen. The neutron source generates fast neutrons with energies from 0.5 to 12 MeV with mean energy of about 4 MeV.

3. Conclusions

Schottky barrier detector based on 4H-SiC high quality epitaxial layer was investigated. Current-voltage measurements show very low saturation current below 1×10^{-10} A/cm^2 at -100 V. The current raised at higher voltages more steeply as no guard ring was used. The best energy resolution obtained by detection of alpha-particles from ^{241}Am radioisotope was 58 keV in FWHM. The detector reached almost 100% CCE at voltages higher than -150 V. The detector structure was also used for detection of fast neutrons from ^{239}Pu-Be source. Detected spectrum consisted of two parts corresponding to silicon and carbon recoils.

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