Fabrication and characterization of N-type HPGe detector

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Introduction

Radiation detectors based on high-purity Ge (HPGe) are extensively used for their excellent energy resolution and good efficiency [1]. These detectors are simple in design but involve complex and sensitive processing. Typically an HPGe detector consists of a single piece of HPGe with two electrical contacts fabricated on it for bias application and charge collection. These contacts must block charge carrier injection to achieve as low leakage current as possible to minimize noise. The industry standard utilizes impurity based contacts; B implantation to form a p+ electron blocking contact, while Li diffusion is used to form a thick and robust n+ hole-blocking contact.

In this paper we are presenting the work done on the fabrication of gamma detector using an n-type HPGe crystal. The main emphasis will be on the process of diode fabrication that involves mechanical processing of ingots/single crystal into desired shape and size followed by chemical treatment of the surface to obtain defect free pristine surface for contact fabrication and surface passivation.

Detector Fabrication and Testing

Detector fabrication was started with a cylindrical n-type HPGe monocrystal with the dimensions of 26 mm diameter and 26 mm height. The HPGe crystal was procured from Umicore, Belgium [2] that had a impurity concentration of 0.85×10^{10} cm−3 and 1.2×10^{10} cm^{-3} at the top and bottom planes, respectively. The crystal was cut in to sample of 26 mm dia and 16 mm length using a diamond impregnated blade saw for further processing. The cut sample was lapped from all side to a surface finish of ~ 10 micron using SiC emery papers of grit size from 220 to 1500 followed by lapping using 9 micron alumina slurry on a polishing cloth. All the lapping and polishing was done in wet condition to minimize the surface damages during the process. Mechanically processed sample was etch-polished using a solution of HF-HNO_3 mix in 1:3 ratio. Etching time and etchant concentration was optimized to obtain damage free surface.

For fabrication of n+ contact (Hole blocking) Li was thermally evaporated on one of the flat surface followed by diffusion at 300°C for 20 min. To obtain a clean surface and good electrical contact after Li diffusion the crystal was again etched in the 3:1HNO_3:HF mixture to remove any excess of lithium. After taking Li contact, a 10 mm deep grove of 16 mm ID and 1mm width was cut in the sample around it (Fig.1) using a core drill bit and Alumina slurry of 30 micron size. After fabrication of grove the n+ contact was protected by wax and the sample was again etched for 10 min in the 3:1 HNO_3:HF solution to remove the mechanical damages on the groove surface.

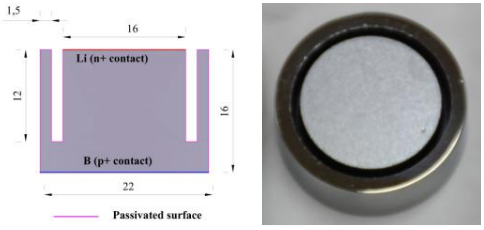

Fig. 1 Cross sectional view of the HPGe diode (left) and actual photograph of fabricated diode(right).

The p+ contact (electron blocking) was created on face opposite to n+ contact by Boron implantation. Danfysik (1080-30) ion implantation system was used for the purpose. The implantation was performed with ions of energy: 25keV, with dose of 10^{14} ions/cm^2.

Implantation was done at room temperature and no annealing of the sample was performed after implantation.

After fabrication of both the contacts, well defined gold was deposited on the contacts for metallization. Finally, the sample was etched in a 8:1 HNO_3:HF solution for chemical passivation of the inter-contact surface. After complete process the diode was mounted in cryostat for the detector performance testing and diode characterization at 100 k. Electronic circuit used for detector testing is shown in fig.3.

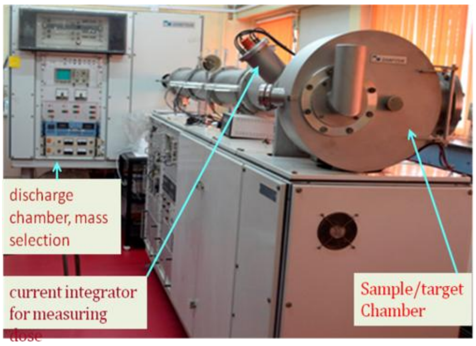

Fig. 2 Photograph of ion implanter (Danfysik 1080-30).

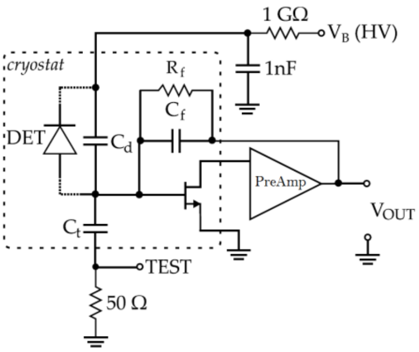

Fig. 3 Diagram of test circuit.

To record the I-V characteristic two terminals; (i) terminal used for biasing (HV) and (ii) gate terminal of JFET were used. A external high voltage source was used for biasing and a keithley electrometer 6517b was used to measure current. The I-V characteristic is shown in fig.4. Diode under testing shows <1 pico-ampere current upto 550 volt, beyond this current increased to 100 pico-ampere at 1200 volt. The step increase in leakage current at 550 indicates the full depletion achieved. Detector performance was tested using ^{137}Cs source. We achieved a FWHM of 2keV at 662 keV, also at low energy 32keV and 36 keV x-ray peaks were well resolved (Fig.5). In conclusion N-Type HPGe detector was fabricated using impurity based contacts and detector shows satisfactory performance. In future efforts are going on in order to increase the detector volume and to better the energy resolution.

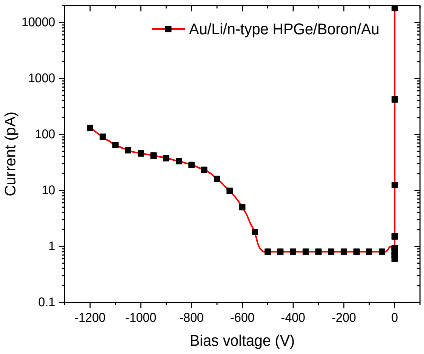

Fig. 4 I-V characteristic of n-type HPGe diode at 100K.

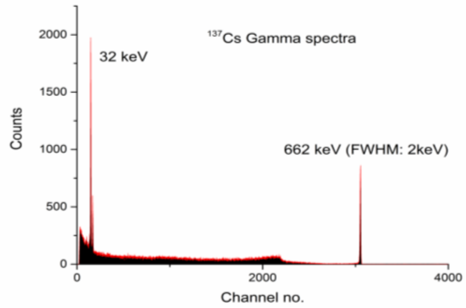

Fig. 5 Gamma spectra of ^{137}Cs recorde by the fabricated detector. (Bias: 1200 V, shaping: 6 micro seconds, count rate: 500 cps).

References

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[2] Umicore,https://eom.umicore.com/en/germanium-solutions/products/high-purity-germanium-crystals/