Fabrication of a Planar P Type High Purity Germanium Detector

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Introduction

High Purity germanium (HPGe) detectors are found to be suitable for nuclear techniques for measuring radionuclides with very good energy resolution. Formation of charge non-injecting contacts and intercontact surface passivation to achieve low leakage current are two foremost challenges associated with the HPGe detector fabrication. As a result, the fabrication recipes of commercially available detectors are proprietary in nature. Existence of a space charge layer at the free surface of germanium is a well identified problem which makes the surface conductivity of Ge different from that of the bulk **[1]**. For a P type crystal, rugged hole blocking contacts (n^+) are formed by lithium diffusion and p+ (injecting) contacts are produced using Boron ion implantation. The Ion implantation facilities are, in general, complex and expensive and could be bypassed provided there is a sufficient distribution of acceptor states (p^+) on P type Ge bulk crystal. Oxidation etches can replicate the effect of boron doping by creating adequate acceptor like states. A metal layer on the oxidized surface then produces good charge injection contact. The objective of this work is to demonstrate the functionality of a planar p type HPGe detector fabricated by circumventing the complex ion implantation process. Electrical and detection properties of the prototypes have been characterized, showing low leakage currents and good spectroscopy data with different gamma-ray sources.

Detector Fabrication

A p-type HPGe crystal (Umicore Inc., Belgium) having net carrier concentration ≈ $10^{10}/cm^3$ was cut using diamond impregnated wheel saw in a top hat geometry as shown in **Fig.1**. The bottom area is 22mm×22 mm and the top part is 16mm×16 mm. The chosen geometry facilitates crystal handling during various processing steps and also enables the pinching off of surface channels that makes passivation less critical.

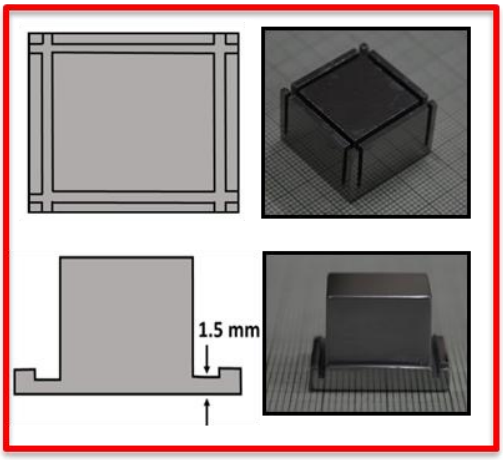

Fig. 1 Cross-sectional view and actual shaped 16 mm thick Top-hat crystal.

The cut sample was lapped from all side to a surface finish of ~ 10 µm using SiC emery papers of grit size ranging from 220 to 1500 in wet condition to avoid heating related surface damage. Final mechanical surface finish was given by lapping the crystal using 9 µm alumina slurry. Crystals were chemically polished in a solution of CMOS grade $HF:HNO_3$ mixture (1:3) until a smooth damage free surface with mirror finish was obtained. The etch was rapidly quenched in DI water and crystal was rinsed multiple times. n^+ rectifying contact was produced by thermal evaporation of Li metal on one of the flat surface followed by diffusion at 300°C for 15 min in Argon in a custom built thermal evaporation-diffusion chamber as shown in Fig. 3. The base vacuum was 5×10^{-6} mbar. The crystal is cooled within 30 mins to achieve a saturated Li concentration. Diffusion depth and sheet concentration of Li was found to be 250µm and $10^{17}/cm^3$ respectively. Excess Li was removed in Methanol and crystal was subjected to 30 sec short etch to achieve a clean lithiated surface.

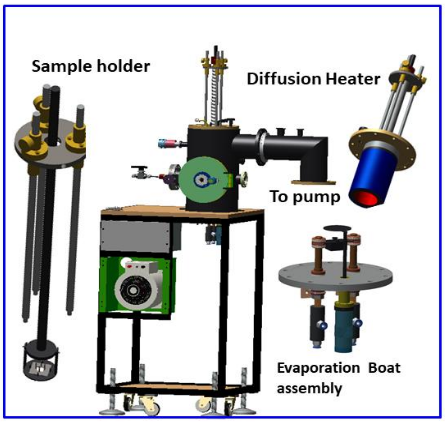

Fig. 2. A 3-D model of custom built Lithium evaporation and diffusion set-up.

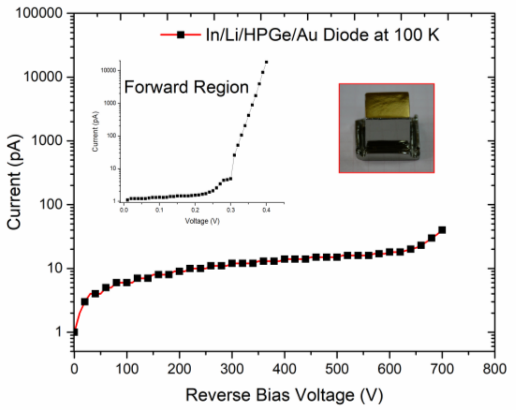

Fig. 3. Reverse and forward characteristics of p-type planar HPGe crystal. Actual photograph of prepared device is also shown in the inset.

The lithium contact is masked using etch resistant Apeizon wax and the crystal is subjected to oxidation etch in HF:H_2O_2 mixture as described in Ref. **[2]**. 40µg/cm^2 Au is deposited on the oxidized surface which adheres strongly on the chemically grown oxide layer. Finally, protecting both contacts, the device is etched for 3 mins in HF:HNO_3 (1:8) mixture and loaded in a vacuum cryostat cooled to 100 K for leakage current and detection response tests. The diode exhibits less than 100pA leakage at 700 volt reverse bias as shown in Fig. 3. The response of detector to ^{137}Cs source is shown in Fig. 4. The crystal housing (shown as inset picture) has also been developed in-house. The detector is operated above full depletion at 750 V. Typical line-width of 662 keV energy peak is 2.1 keV. The low energy 32keV and 36 keV x-ray peaks are seen to be well resolved.

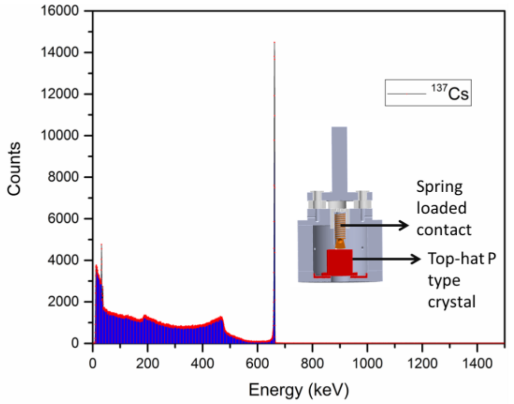

Fig. 4 Gamma spectra of ^{137}Cs as recorded by the fabricated detector. (Bias: 750 V, shaping: 6 µs, count rate: 500 cps).

Conclusion

P-Type HPGe detector was successfully fabricated using Li and Au contacts employing indigenously developed tools and set-ups. Need for complex ion implantation process could be eliminated using oxidation etch and subsequent Au evaporation. However, it needs to be emphasized that rugged rectifying contact on N type crystal may still require ion implantor tool. In future, the technology will be scaled up to fabricate large volume detectors.

References

[1] H. Statz, G. deMars, L. Davis, Jr., and A. Adams, Jr., Phys. Rev. 106, 455 (1957).
[2] Ewins, J., & Llacer, J., IEEE Trans. on Nucl. Sci., 21(1), 370–373 (1974).