# Fabrication of a P-type HPGe small-anode geometry detector


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## Introduction

High-purity germanium (HPGe) detectors are considered as best in class semiconductor radiation detector because of its superior energy resolution and good efficiency [1]. Quest for new type of detector is continuing for special purpose experiments in nuclear and particle physics despite variety of HPGe detectors available commercially. Point-contact HPGe detectors are fabricated by forming a small area contact which is separated from the wrap around contact through a groove. These detectors are particularly attractive for their low energy thresholds and excellent energy resolution over a wide energy range. In addition, it has low capacitance even for large detector dimensions [2]. A low capacitance allows for low noise levels, which leads to superior energy resolution and low energy thresholds. This feature makes the technology important for experiments in nuclear and particle physics, such as searches for dark matter, coherent neutrino-nucleus scattering, and neutrinoless double beta decay.

In this paper we report the fabrication of small anode geometry p-type HPGe detector. The process of diode fabrication 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

Typically, an HPGe detector consists of a single piece of HPGe crystal with two electrical contacts fabricated on it for bias application and charge collection. These contacts must block charge carrier injection to achieve low leakage current 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.

Detector fabrication was started with a cylindrical p-type HPGe mono-crystal with the dimensions of 50 mm diameter and 25 mm height as shown in Fig. 1. The HPGe crystal was procured from Umicore, Belgium having a net impurity concentration of $0.85\times10^{10}$ $cm^{-3}$ and $1.2\times10^{10}$ $cm^{-3}$ at the top and bottom planes, respectively.

The cut crystal was lapped from all sides to a surface finish of ≈10 µm using SiC emery papers of grit size from 220 to 1500. All the lapping and polishing was done in wet condition to minimize the surface damage. Mechanically processed sample was etch-polished and the etching time and etchant concentration was optimized to obtain damage free surface.

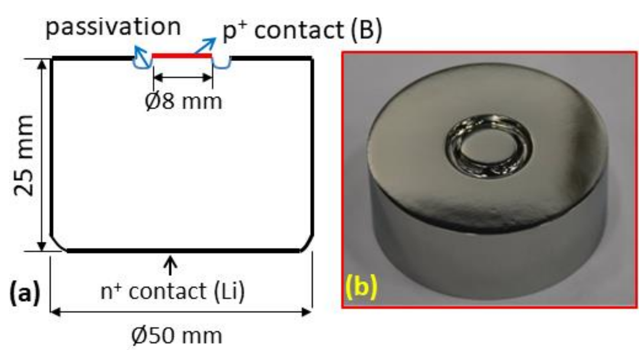


**Fig. 1 (a)** Schematic of fabricated prototype detector with lithium wrap around contact and boron small area contact represented by thick black and red lines respectively and (b) Photograph of actual fabricated detector.

A dedicated system for thermal evaporation of Lithium and its diffusion, as shown in Fig. 2, was fabricated and employed for the fabrication of n+ contact (Hole blocking) on one of the flat surface and curved surface of crystal.

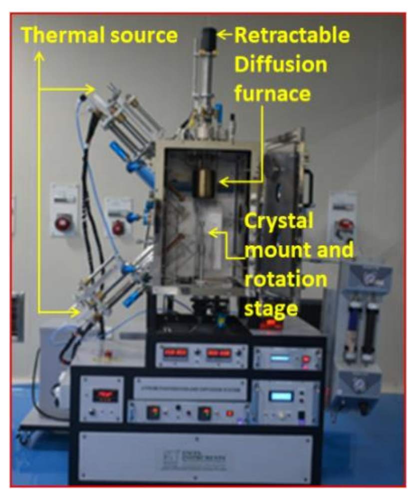


**Fig. 2** Photograph of thermal evaporation and diffusion system for fabricating Li contact in a wrap-around configuration.

The evaporation of lithium at $5\times10^{-6}$ mbar was followed by in-situ diffusion under high purity Argon gas. Excess lithium was then washed away by ultrasonication in methanol. To obtain a clean surface and good electrical contact after Li diffusion, the crystal was again etched in the 3:1 $HNO_3$:HF mixture. The resistivity of Li diffused contact was measured to be less than 2Ω-cm which is typical for a highly doped contact. After taking Li contact, a 3 mm deep groove of 8 mm ID and 2 mm width was drilled (Fig.1 (b)) using a S.S core drill bit and $Al_2O_3$ slurry of 30 µm size. Extreme care was taken while drilling the groove to avoid chipping and surface damages. After fabrication of grove, the n+ contact was protected and the sample was again etched for 3 min in $HNO_3$:HF mixture to remove the mechanical damages from drilling process. The $p^+$ contact (electron blocking) was created by Boron implantation using a Danfysik (1080-30) ion Implantor. The implantation was performed at room temperature by mass selection of $^{11}$B ions at 23 keV energy with dose of $5\times10^{14}$ ions/cm$^2$.

Finally, after the groove passivation treatment, the crystal was mounted in a dedicated holder and installed with the front end electronics in a vacuum cryostat. The detector exhibited leakage current of ≈ 20pA at 1500 V bias voltage at temperature of 95K. Depletion region was identified from the current-voltage characteristics (not shown here) when there was step increase in leakage current after 500V. The cold-mount electronics consisted of JFET 2N4393 pre-amplifier first stage, 1pF capacitor and 1GΩ resistor feedback elements mounted closed to JFET gate terminal. The charge signal coming from the small $p^+$ read-out electrode is sent to the BMC1521 HMC based low noise compact charge-

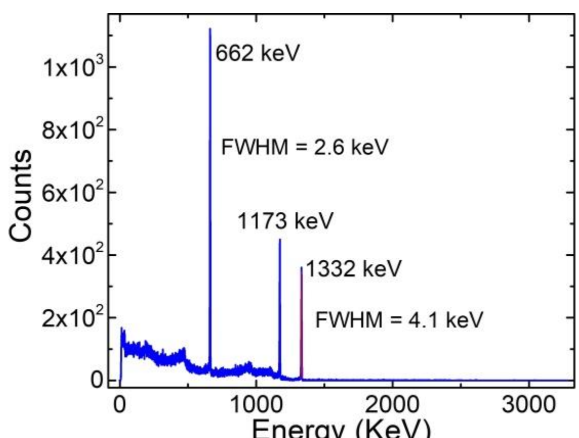


**Fig. 3** Gamma ray spectra from $^{137}$Cs and $^{60}$Co sources recorded by the fabricated detector.

sensitive preamplifier which is integrated in the detector housing. The preamplifier output signals are processed using analogue electronic chain, with a spectroscopy amplifier CAEN Mod.N968 and a Multi-Channel Pulse Amplitude Analyzer TUKAN 8k. Spectroscopic tests were performed by irradiating the detector with calibrated sources and the test result is shown in Fig. 3. The detector specifications and performance are summarized in table 1.

**Table 1**. Geometrical and Electrical parameters of fabricated detector.

| | |
|---|---|
| **Physical characteristics:** | |
| Active diameter | 50 mm |
| Active volume | ~45 cm$^3$ |
| Thickness (active) | 25 mm |
| Distance from entrance window | 5 mm |
| Window thickness (Al) | 1.5 mm |
| Dead layer thickness | 0.6 mm |
| **Electrical characteristics:** | |
| Depletion voltage | 500 V |
| Operating Bias voltage | 800 V |
| **Energy resolution:** | |
| FWHM (662 keV): | 2.6 keV |
| FWHM (1.332MeV): | 4.1 keV (6 µs shaping time) time) |

## Conclusion

The fabrication process of a P-type HPGe detector in small-anode configuration is presented. Custom built tools and set-ups are employed to build the detector. Preliminary spectroscopic performance of the detector is encouraging. The described configuration may not be optimal and further improvement in the resolution is expected after optimization of the electronics.

## Acknowledgement

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## References

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