INTRODUCTION

The interest in large volume HPGe detectors is in their higher efficiency for gamma ray detection, in particular for high energy gammas. When a gamma ray undergoes a Compton interaction or pair production, and a portion of the energy escapes from the detector volume without being absorbed, the background rate in the spectrum is increased and the full energy part of the spectra lose statistics. Larger detector volumes reduce this effect. For high energy gamma rays, this counting reduction effect is very high.

The most efficiently way to polarize a large volume Hyperpure Germanium (HPGe) detector, is to adopt the true coaxial or single-ended coaxial geometries (Fig.1)[1].

The coaxial single-end geometry permits to have lower leakage current than the true coaxial because has only one passive surface between two contacts [4]. To realize the internal contact, (p or n type) it is necessary to drill the HPGe crystal with techniques that do not introduce defects and in particular dislocations that would change the nature of the HPGe material.

This work describes a simple homemade new system for drilling HPGe crystals for making true or single-end coaxials or even well-type detectors.

THE DRILLING SYSTEM

The mechanical lapping is the optimize method of the germanium surface polishing. The ceramic slurry is composed by bidistilled water (BDW) and micrometric powders (3 to 30 μm) of alumina. This viscous mixture realized between the tip and the surface of the crystal and by the sample rotation polished the material.

The drilling system represented in Fig. 2 designed by 3D software permits to optimize the geometry and the mechanical couplings. It is composed of a crystal holder that rotated around its cylindrical axis. The hole is realize by a custom tip, loaded by a weight that permits to keep the ceramic slurry on the surface of HPGe crystal.

Fig. 1 Typical geometry of HPGe detector

Within our R&D program for developing high efficiency and high resolution gamma tracking detectors, we are now starting to apply to coaxial crystals the new technologies that we are developing for smaller planar detectors.

The HPGe material has typically a net impurity concentration < 10¹⁰ atoms/cm³. This value of impurity permits to obtain high efficiency and energy resolution [2]. The dislocations number in HPGe semiconductor is important because as traps for holes which decreases the charge collection in the detector and hence the energy resolution. Usually the dislocation density < 10000 cm⁻² (p-type) and < 5000 cm⁻² (n-type) [3].

For modifying the geometry of high purity germanium (HPGe) crystals, i.e. the external shaping in cylindrical tapered or hexagonal shapes and the internal coaxial drilling, it is necessary to avoid both surface contaminations and mechanical stress that could increase the number of defects or dislocations in the volume and/or the surface.

General processes for shaping Ge crystals have been studied and several techniques have been proposed like i.e. ultrasound shaping, but a without providing any prove of their application for the production of a good quality detector.

The holder has to fix the crystal without mechanical stress, because is made an elastic material. The drilling depends on the amount of clean ceramic slurry that remains in between the tip and the crystal.

Fig. 2 3-D design scheme of drilling system
To avoid the pollution of the hyperpure germanium all the recirculating circuit of the ceramic suspension is made of natural PTFE (Polytetrafluoroethylene) (Fig. 3).

To maintain the ceramic slurry in suspension it was necessary to keep the suspension in motion with a PTFE + EPDM membrane pump and a PTFE pipes with two tanks in PTFE to realize a recirculating circuit (Fig. 4).

The crystal sample holder rotated < 70 rpm by a speed control motor that permits to have a drilling rate < 0.5 mm/h (Fig 5). We are now trying to determine the optimum parameters (rotation speed, slurry density, slurry flow speed, weight on the tip, Al₂O₃ grain size, etc.), at least for this hole size.

The Fig. 3 shows the PTFE tubes that carry the ceramic slurry between the tip and the surface of the crystal. The slurry is kept in motion by a PTFE brush so as to maintain a homogeneous slurry.

Fig. 3 PTFE tubes and the crystal holder.

The Fig. 4 Closed suspension circuit: (A) PTFE membrane pump, (B) PTFE pipes and (C) PTFE tank.

CONCLUSIONS

The R&D on coaxial drilling contact is of great importance to realize gamma detector with good resolution at higher energy.

The use of non-contaminating materials such as PTFE throughout the recirculating circuit of the ceramic suspension allows processing of the hyperpure germanium crystal without changing its purity degree. Drilling technology with dispersed alumina powders removes the material reducing the defects/dislocations number in the HPGe crystal.

After the mechanical process, the crystal will be etched with 3:1 (HNO₃ : HF) to remove the surface defects/dislocations introduced by mechanical drilling, and prepare the HPGe crystal chemical surface passivation [5].

REFERENCE AND ACKNOWLEDGEMENTS

This work is supported by INFN, University of Padova and by the European H2020 Program, under grant agreement No. 654002 – ENSAR2 -INFRAIA, WP10-JRA2 PseGe.

I would like to thank the mechanical workshop for support in the implementation and realization of this drilling prototype system.