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RADIATION DAMAGE RESISTANCE OF REVERSE ELECTRODE GE COAXIAL DETECTORS

Richard H. Pehl*, Norman W. Madden*, Jack H. Elliott**
Thomas W. Raudorf+, Rex C. Trammell+ and Lawrence S. Darken, Jr.+

Summary

Two high-purity germanium coaxial detectors, having opposite electrode configurations from one another, but fabricated from the same germanium crystal, were irradiated simultaneously with fast neutrons from an unmoderated ^{252}Cf source. Both detectors were 42 mm diam. The detector having the conventional electrode configuration was about 28 times more sensitive to radiation damage than was the detector having the p^+ contact on the coaxial periphery.

These results prove that germanium coaxial detectors having the conventional electrode configuration should not be used in any situation subject to significant radiation damage. This conclusion was anticipated because the defects produced by neutron and proton irradiation of germanium act predominantly as hole traps.

Introduction

It has been known for a number of years that fast neutron irradiation of germanium detectors produces predominately defects which act as hole traps.[1] This fact leads to consideration of the possibility of minimizing hole trapping in charge collection by the use of a high-purity germanium coaxial detector configured with the p^+ contact on the periphery of the coaxial structure.[2]

As depicted in Fig. 1, most of the holes produced by gamma-ray interactions will then make only a short traversal from the outer portions of the detector (where most of the interactions occur because of geometry) to the contact. To establish a high electric field at the periphery n-type germanium should be used. In the conventional high-purity and lithium-drifted germanium coaxial detectors the hole collection process dominates the signal, whereas when the electrode configuration is reversed as discussed here the electron collection process dominates the signal. Thus a coaxial detector having a reversed electrode configuration should be less sensitive to radiation damage.

In the course of a continuing study of the proton damage of germanium detectors data were obtained that implied an improvement in radiation damage resistance of about 60 times when comparing very large coaxial detectors having the opposite electrode configuration.[3,4] However, this factor was obtained via a series of indirect comparisons, and was possibly subject to some error. The purpose of the work reported here is to directly test this hypothesis and to determine the magnitude of the improvement.

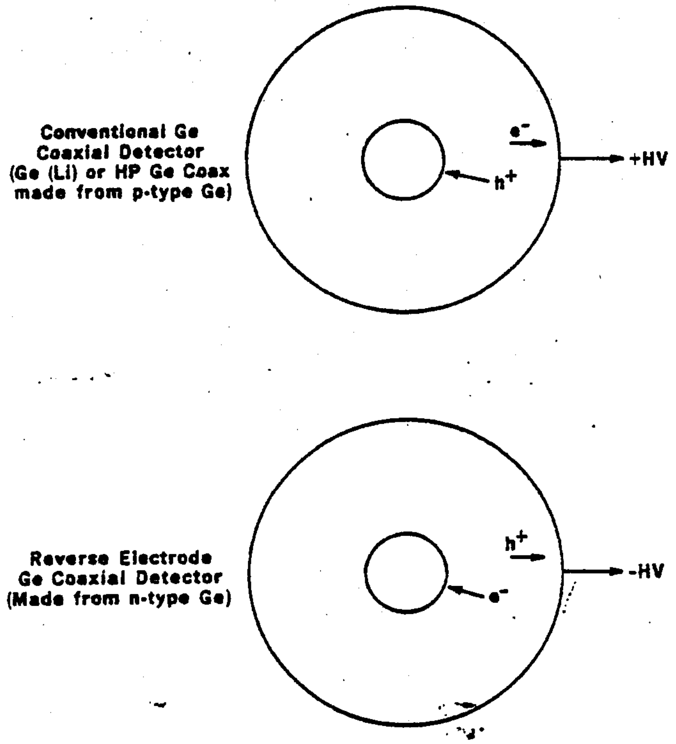

Fig. 1. Charge collection directions for holes and electrons in the conventional Ge coaxial detector and in the reverse electrode Ge coaxial detector.

Experimental

Two high-purity germanium coaxial detectors that were fabricated from the same germanium crystal grown at EG&G ORTEC[5] were irradiated with fast neutrons from an unmoderated ^{252}Cf source at the Lawrence Livermore Laboratory Hazzards Control Standards and Calibrations Laboratory.[6] In light of the range of radiation damage sensitivities among detectors made from different crystals[7] it is important that comparisons be made from detectors fabricated from the same crystal if possible. The fortuitous variation of the net electrically active impurity concentration in the crystal illustrated in Fig. 2 allowed the fabrication of coaxial detectors having the opposite electrode configurations from nearly adjacent pieces of material. Only a 4 mm thick material evaluation slice was taken between the germanium pieces from which the detectors were fabricated. As expected because of the various effective impurity distribution functions, the material for the detector having the conventional electrode configuration came nearer the head of the crystal. Although the two detectors were mounted in separate cryostats cooled with LN_2 both detectors were maintained at essentially the same temperature.

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*Lawrence Berkeley Laboratory, University of California, Berkeley, California 94720, U.S.A.,
**Lawrence Livermore Laboratory, University of California, Livermore, California 94550, U.S.A.
+E.G.&G. ORTEC, 100 Midland Road, Oak Ridge, Tennessee 37830, U.S.A.

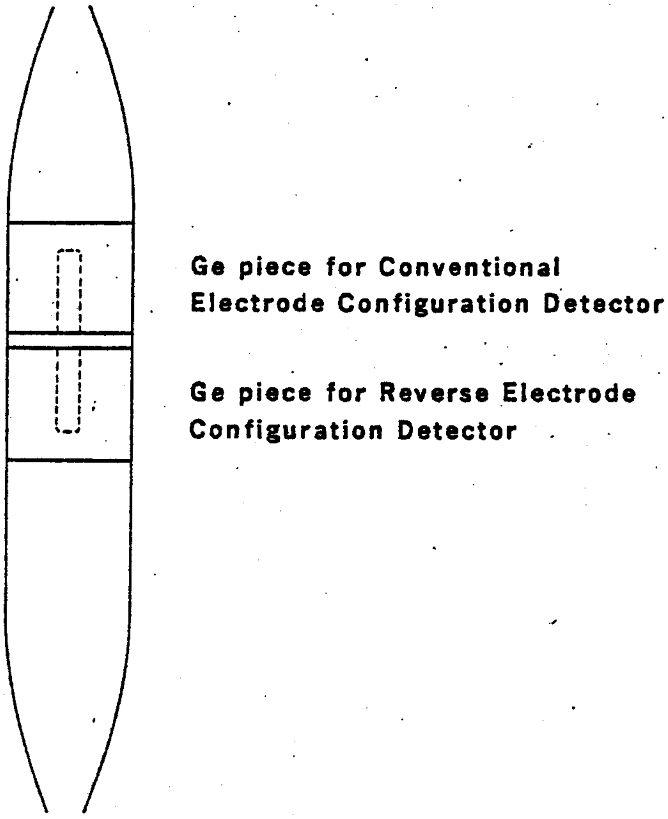

Fig. 2. Schematic illustration of the germanium crystal showing the location of the pieces from which the two coaxial detectors were fabricated.

Various detector parameters are listed in Table 1.

Table 1

	Detector	
	Conventional Electrode Configuration	Reverse Electrode Configuration
Diameter	42 mm	42 mm
Center Hole Diameter	8 mm	8 mm
Length	30 mm	30 mm
Relative Efficiency at 1332 keV	7%	7%
Depletion Bias	850 V	2600 V
Maximum Operating Bias	1800 V	3000 V
Operating Bias During Experiment	1600 V	2800 V

Resolutions for the 1332 keV ^{60}Co line, measured in the experimental configuration at the Standards and Calibrations Laboratory prior to the start of the irradiation, were 1.8 and 2.0 keV (LBL amplifier, 4 μs peaking time) for the reverse and conventional electrode configuration detectors respectively. The small difference arose because of additional pick-up that could not be eliminated at the time. The pulser resolutions were 1.0 and 1.3 keV, respectively.

The ^{252}Cf source gave off 1.26×10^9 neutrons per sec, thus with the detectors located 25 cm from the source they received a flux of 9.63×10^6 n/cm^2 per minute. The experimental plan was to irradiate the detectors simultaneously with a given neutron fluence, then measure the resolution of the gamma-ray lines from a ^{60}Co source. Then a further irradiation would be made, and the resolution measured again. This procedure was followed until the magnitude of the difference in sensitivity to radiation damage between the two detectors was clearly determined.

Results And Discussion

Figures 3 and 4 convey the crux of the measurements. Little more needs to be said other than emphasizing the magnitude of the huge difference in sensitivity to radiation damage. The coaxial detector having the reverse electrode configuration is about 28 times less sensitive to the fast neutrons from the ^{252}Cf source, i.e. this detector will withstand 28 times greater neutron fluence before suffering equivalent energy resolution degradation. This difference would be even greater if the coaxial detectors were fabricated from larger diameter crystals. Thus, these results are in essentially perfect agreement with the predicted decrease in sensitivity to radiation damage of 60 times when comparing very large, approx. 60 mm diam., coaxial detectors having the opposite electrode configurations.[4]

The evidence is now overwhelming that germanium coaxial detectors having the conventional electrode configuration should not be used in any situation where they are subject to significant radiation damage. The growing availability of germanium coaxial detectors having the reverse electrode configuration should make the use of large germanium detectors viable for many additional applications that were previously marginal or impractical because of radiation damage problems.

Acknowledgment

Eugene Haller, Fred Goulding and Larry Varnell provided useful discussions. This work was supported by the Nuclear Science Division of the Department of Energy under Contract No. W-7405-ENG-48.

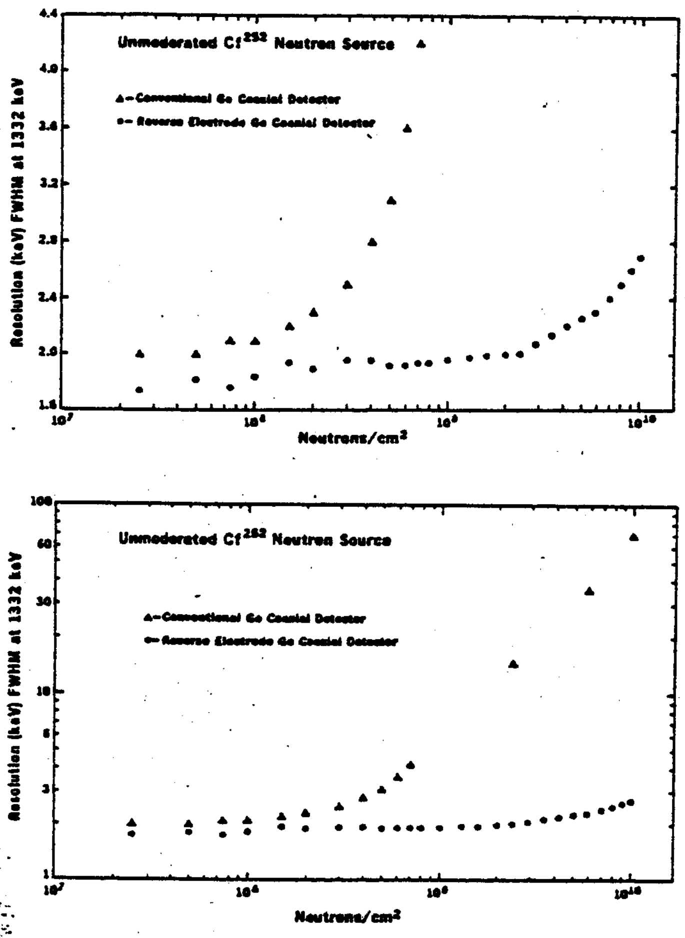

Fig. 3 Effect of neutron fluence on the energy resolution (FWHM) of the 1332 keV ^{60}Co line for both the conventional and reverse electrode configuration Ge coaxial detectors. Electronic noise has not been subtracted.

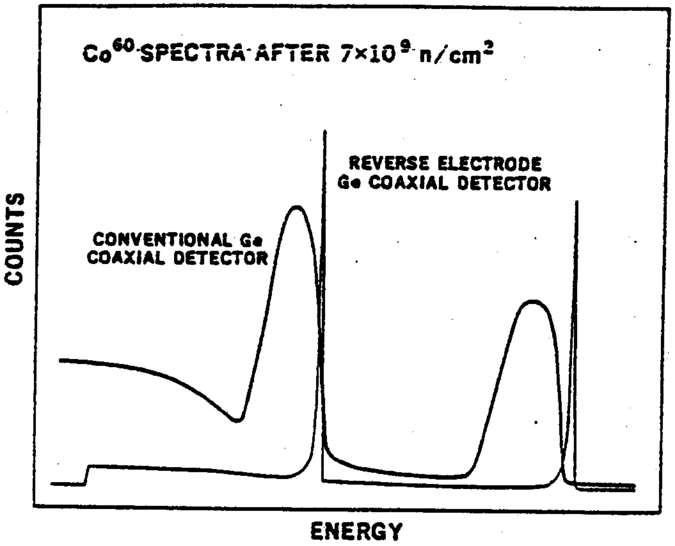

Fig. 4. ^{60}Co energy spectra obtained from both the conventional and reverse electrode configuration Ge coaxial detectors after a neutron fluence of 7 x 10^9 n/cm^2.

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