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August 1969

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# THIN-WINDOW GERMANIUM DETECTORS: FALLACY AND FACT

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## ABSTRACT

Results demonstrating the successful use of a gold surface-barrier as a thin-window $p^+$ termination of the intrinsic region of a lithium-drifted germanium detector are reviewed; these results are a rebutal to statements recently made by Dearnaley et.al. in this journal.

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## I. INTRODUCTION

The purpose of this brief note is to refute some erroneous and misleading statements recently published in this journal by Dearnaley et.al.[1]. We speak from our own experience but would like to note that other groups observe similar results, and that devices similar to ours are commercially available.

For more than five years we have been routinely making thin-window detectors using the gold surface-barrier technique[2]. About 40 successful detectors have been produced and used without a single failure caused by the surface-barrier contact*. These detectors are commonly used for photon measurements, and occasionally for charged particle measurements.

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* We would like to differentiate here between the conventional type of gold surface-barrier used on n-type material and its use as a $p^+$ termination of the intrinsic region in a lithium-drifted detector. In the latter case, at least in silicon detectors, our observations strongly indicate that the performance is much less sensitive to the environment, damage and edge effects than is the conventional surface-barrier. This has led us to question whether the mechanism of operation of the barrier is the same in the two cases.

Figure 1 compares a typical voltage-current curve for one of our detectors against the "low reverse current" detector of Dearnaley et.al.[1]. This dramatically demonstrates that "excessive" reverse current is not present in our surface-barrier detectors, and that the detector described in ref. 1 would not be considered acceptable by our reverse current standards. A possible explanation of the shape of the V-I curve presented in ref. 1 is that the gallium implanted layer is not providing a sufficiently $p^+$ contact.

As for the unstable characteristics of germanium surface-barrier devices alluded to in ref. 1, the detector shown in fig. 1 has been in almost continuous operation for nearly four years, and we have about ten other detectors that have been in operation over two years. In fact there has been no case where detector degradation has forced removal of a thin-window detector. (Except due to radiation damage in detectors used near accelerators.)

In 1965 we used these thin-window germanium detectors to measure protons up to 40 MeV[3,4]. Similar work was reported by Bertrand, et.al.[5]. Although this program has received little emphasis, a total system resolution of 17 keV for 42-MeV protons has now been obtained[6]. (This includes the cyclotron beam-energy spread, electronic noise, detector statistics and other sources of signal spread.)

As discussed previously,[7] maintaining an extremely thin window presents some problems, but we have no difficulty maintaining a considerably thinner window than Dearnaley et.al.[1]. Fig. 2 shows a $^{228}$Th alpha particle energy spectrum obtained using a surface-barrier entrance window; a comparison of this spectrum with the alpha particle spectrum presented in fig. 3 of ref. 1 is quite enlightening. Our nearly symmetric peak at 5.427 MeV with a resolution of 14 keV compares quite favorably with their very asymmetric peak with a resolution of 200 - 300 keV.

Figure 3 shows the type of high quality gamma-ray spectrum that can be obtained with surface-barrier thin-window detectors. This spectrum was recently obtained from the detector discussed in conjunction with fig. 1. Somewhat better resolution has been obtained using a smaller detector surrounded by a cold shield to reduce IR-induced leakage current.

In conclusion we would like to say that our purpose in this note is to emphasize to other groups that the surface-barrier technique can provide a very satisfactory method of achieving the p+ entrance window for lithium-drifted germanium detectors. We do not wish to indicate any lack of interest in ion-implantation which has its own attractive features independent of techniques which compete in a particular application.

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4) R. H. Pehl, D. A. Landis and F. S. Goulding, IEEE Trans. Nucl. Sci. NS-13, No. 3, (1966) 274.

5) F. E. Bertrand, R. W. Peele, T. A. Love, R. J. Fox, N. W. Hill, and H. A. Todd, IEEE Trans. Nucl. Sci. NS-13, No. 3 (1966) 279.

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## FIGURE CAPTIONS

Fig. 1. Comparison of the voltage-current curves for a good (but not unique) gold surface-barrier thin-window lithium-drifted germanium diode against the device shown in ref. 1. Both measurements were made at 77°K. Our detector had a drift depth of 9 mm and an area of 1.2 $cm^2$; the device in ref. 1 had a depth of 4 mm and an area of 2.7 $cm^2$. We believe that the leakage current in our device is due to IR absorption from the walls of the vacuum chamber. Surrounding the detector with a cold shield reduces the leakage to less than $10^{-12}$ amperes. For this particular detector the breakdown voltage exceeded 2.5 KV. (The measurement was not extended to higher biases at the time because an appropriate power supply was not available.) Breakdown voltages greater than 2 KV are typically achieved, and several devices have been used at 4 KV.

Fig. 2. Partial alpha particle energy spectrum from a $^{228}Th$ source. The broadening of the higher energy peaks is caused by the additional effective source thickness seen by alpha particles emitted later in the decay chain due to the recoil of the daughter nuclei.

Fig. 3. Spectrum for $^{60}Co$ gamma-rays in the gold surface-barrier thin-window detector discussed in conjunction with fig. 1.

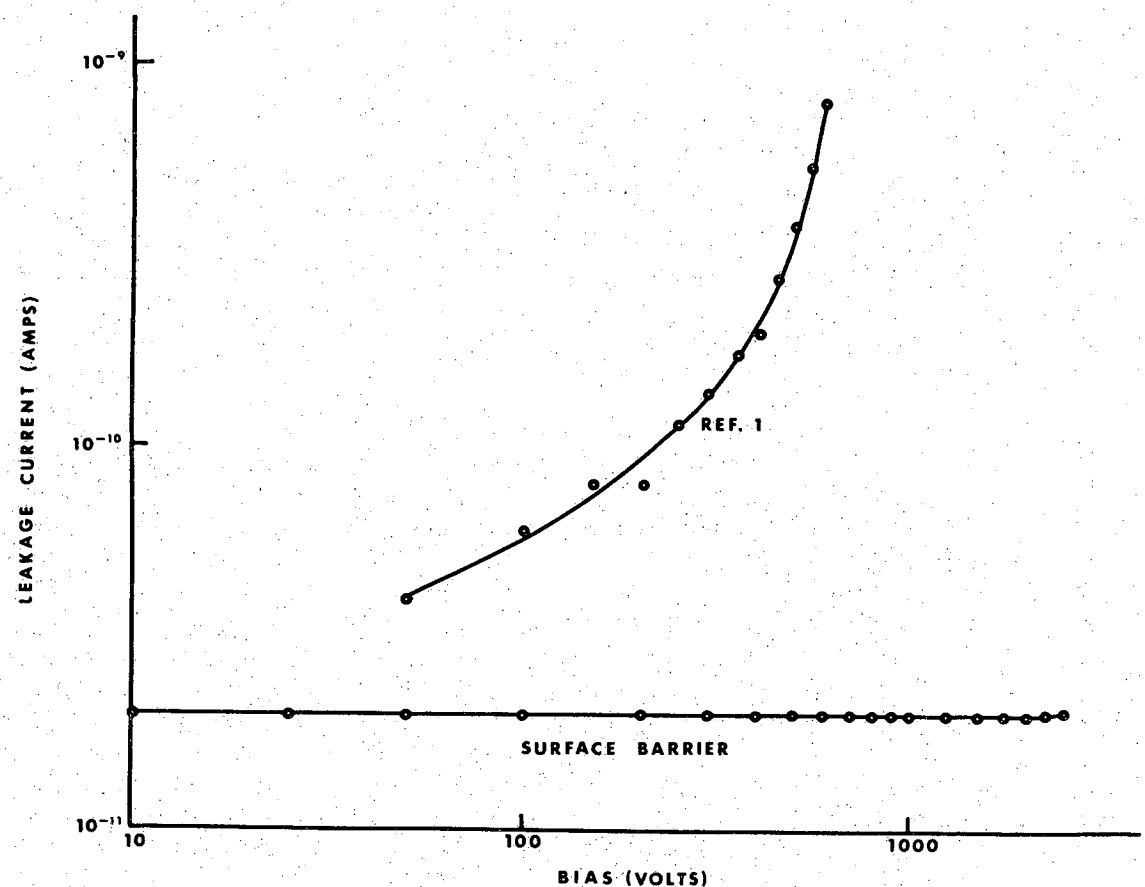


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Fig. 1. Comparison of the voltage-current curves for a gold surface-barrier thin-window lithium-drifted germanium diode against the device shown in ref. 1.

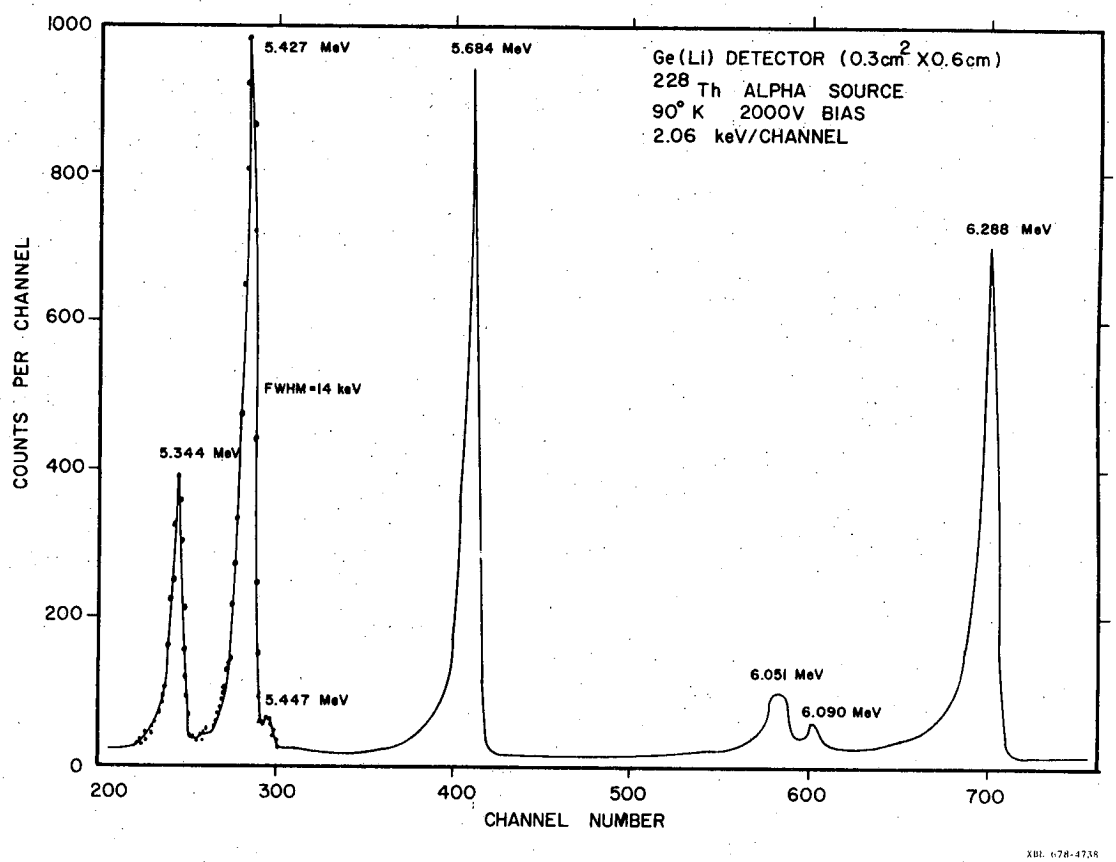


Fig. 2. Partial alpha particle energy spectrum from a $^{228}Th$ source.

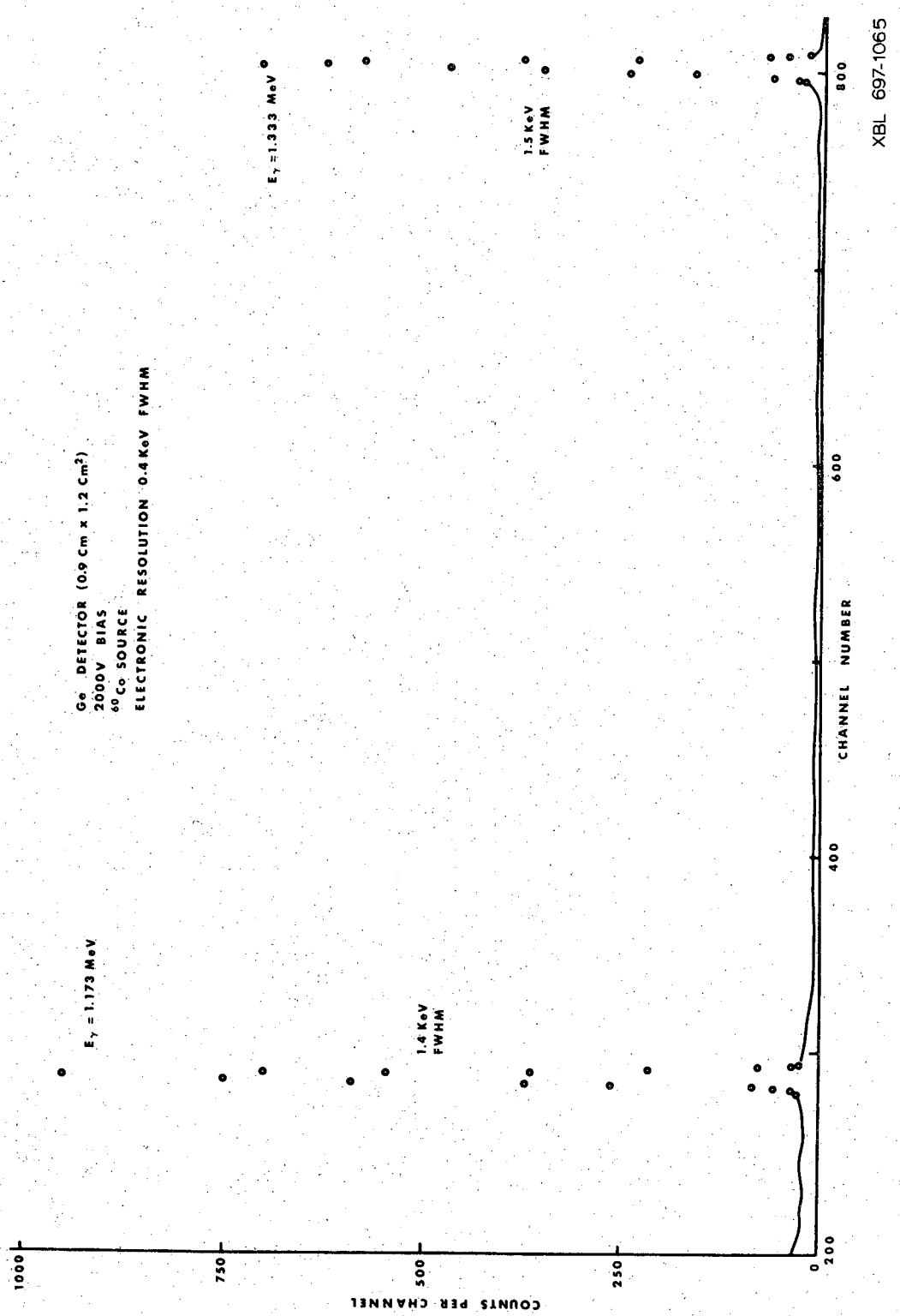


Fig. 3. Spectrum for $^{60}$Co gamma-rays in the gold surface-barrier thin-window dector discussed in conjunction with fig. 1

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