Study of the HPGe detector radiation damages by pulse shape analysis

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Motivation

Application of the HPGe detectors in accelerator driven gamma-spectroscopy experiments is often carried out in an environment rich of fast neutrons and charged particles. Interacting with the germanium, these particles cause radiation damages which are the limiting factor for the life of the detector and useful data collected.

The radiation damages cause an enhanced trapping probability of the charge carriers. Since the detrapping occurs rather late after the charges are collected, it does not contribute to the pulse height and effectively these charges are treated as a DC current. As a result a strong tailing of the low energy slope of the gamma-line is to be observed. Quantification of this tailing is done by the ratio $\frac{FWTM}{FWHM}$ where FWTM and FWHM are the width of the gamma-line at 1/10th and half maximum of the line. It requires a very good statistics and generally is sensitive only to high degree of damage, thus becoming a not good definition for the deformation of the line. In this study we focused our attention on the correlations between the shape of the pulse from the detector and the degree of radiation damage.

Experimental results

The trapping effects distort the pulse shape at its higher part [1]. The incomplete charge collection leads to ballistic deficit, i.e. the pulse is slightly lower. Therefore, comparing the rise times of the pulse at the beginning (the time the pulse to reach 30% of its height) and at the end (the time to pulse to reach from 80% to 100% of its height) sheds light of the effectiveness of the trapping process.

The degree of the radiation damages has been studied experimentally comparing two almost equal HPGe encapsulated detectors (EB capsules) - one has been irradiated by fast neutrons and the other one is undamaged showing good charge collection. Their properties before irradiation have been rather equal, so that any charge carrier traps due to incomplete purification of the material or crystal

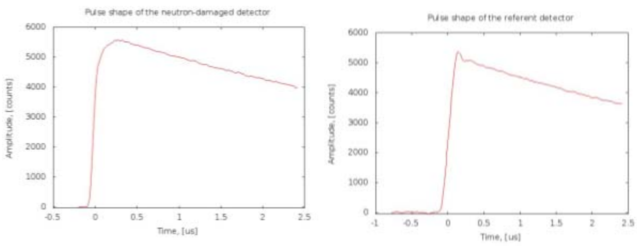

Figure 1: The electron collection dominated pulse shape from a damaged detector (left) and from an undamaged detector (right).

growth process are not supposed to distort the results. The measurements have been carried out by ^{60}Co source and the pulse shapes have been directly digitized after the preamplifier [2]. The waveforms are gated with the 1173 and 1332 keV lines.

The charge carries, in these case electrons, are collected at the core n-contact of the N-type HPGe crystal by an AC-coupled preamplifier. The outer p-contact of the detector is grounded. The signal shapes from the damaged and undamaged detector are shown on Fig.1 left and right respectively. Depending on the position of the interaction, the electrons collection can dominate generation of the pulse (Fig.1 left) or the holes (Fig.2). This study has been limited to the electron collection dominated pulses.

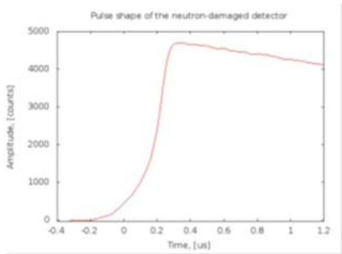

Figure 2: The holes collection dominated pulse from a damaged detector.

The plots of the rise times at the end of the pulse (T80-100) vs. the rise times at the beginning T30 of the pulses for the both detectors are shown on Fig.3, left for the undamaged and right for the damaged ones.

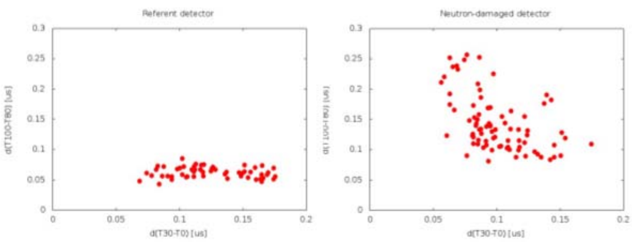

Figure 3: The T80-T100 vs. T30, left is the undamaged detector, right is the damaged one.

The shapes of the pulses coming from the damaged detector clearly differ from those coming from the undamaged ones. Similar effects can be attributed also to the results of the studies [3]. Despite that a comprehensive pulse shape analyse has not been reported, the evolution of the pulses due to the radiation damage suggests a related behaviour.

The statistic of the pulse shapes in this study is not high enough to draw a more detailed conclusion concerning the radiation damage effects. Also a highly damaged crystal has been selected, thus a possible observation thresh-

DOI:10.15120/GR-2015-1-MU-NUSTAR-GS-01

old for the damages degree cannot be stated. Therefore, more comprehensive study of these effects has to be carried out, also with respect of the irradiation evolution.

Acknowledgements

The authors would like to thank to V.Jordanov and the company LABZY, who kindly provided the Multichannel Analyser nano-MCA® used in this study.

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DOI:10.15120/GR-2015-1-MU-NUSTAR-GS-01