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ANALYSIS OF SATELLITE PEAKS GENERATION IN MGR Si DIODE

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ABSTRACT

In this work we present the studies about the origin of the satellite peaks that have been observed in alpha spectra obtained with an implanted silicon diode (type $Al/p^+/n/n^+/Al$). The results have shown that these peaks are due to the induced charge on the signal electrode by the guard rings of the diode. It is also demonstrated that this phenomenon depends on the potential distribution among the guard rings and is less important when they are floating.

1. INTRODUCTION

The performance of a high-resistivity n-type silicon diode with multi guard rings (MGR) structure for alpha particle spectrometry has been recently investigated in our group using a mixed source of ^{239}Pu, ^{241}Am and ^{244}Cm [1-2]. In spite of the good energy resolution obtained, this diode gave rise to some satellite peaks (SP), developed at somewhat lower energies than the main alpha peaks in the spectra.

Since all pulse height distributions were recorded without any diode collimation, the satellite peaks were thought to be due to incomplete charge collection in weak electric field region around the guard rings. To study the origin of this edge effect, we have investigated the spectrometric response of this implanted silicon diode adopting two approaches: use of a diode's sensitive area collimator and change the electric potential of the guard rings connections.

These approaches allowed both the reduction of the diode's border irradiation by alpha particles and the study of the guard rings potential distribution influence on the pulse height spectra, taking into account the relative intensities of the satellite peaks to the main alpha peaks.

The preliminary results have confirmed our initial hypothesis about the origin of satellite peaks and evidenced the importance of the guard rings potential distribution on the edge effects.

2. EXPERIMENTAL ARRANGEMENT

The ion implanted diode (type Al/p^+/n/n^+/Al) under investigation was developed in the framework of the R&D programs for rad-hard silicon detectors to be used in the future CMS experiments at CERN. The device was processed from n-type float zone silicon wafer with a resistivity of about 3 kΩ.cm, 300 µm in thickness and 4 mm^2 useful area.

Since this diode was supplied without electrodes, its electrical leads, as well as the guard rings connections, were made at Microelectronic Laboratory of Sao Paulo University (LME/USP). Dynamic measurements of leakage currents and capacitances of this diode were carried out in the same Laboratory and the results obtained have been published elsewhere [2].

In order to use this diode as a detector, the signal electrode (p^+ frontal layer) was directly connected to the field effect transistor (FET) in the first stage of a charge sensitive preamplifier A250 (Amptek). The positive bias voltage was applied on the n+ diode's back side and the first guard ring (closer to the p^+ electrode) was grounded, while the others were left floating. It is worth noting that with this configuration the diode was not protected against voltage breakdown at all.

This assembly was mounted in a copper plate rivet to the high vacuum chamber's cover as can be seen in Figure 1. The pulses from the A250 preamplifier, due to the alpha particles emitted by a mixed source of ^{239}Pu, ^{241}Am and ^{244}Cm, were shaped and amplified by a linear amplifier (Ortec 572) and fed to a multichannel analyzer (Ortec Spectrum Ace).

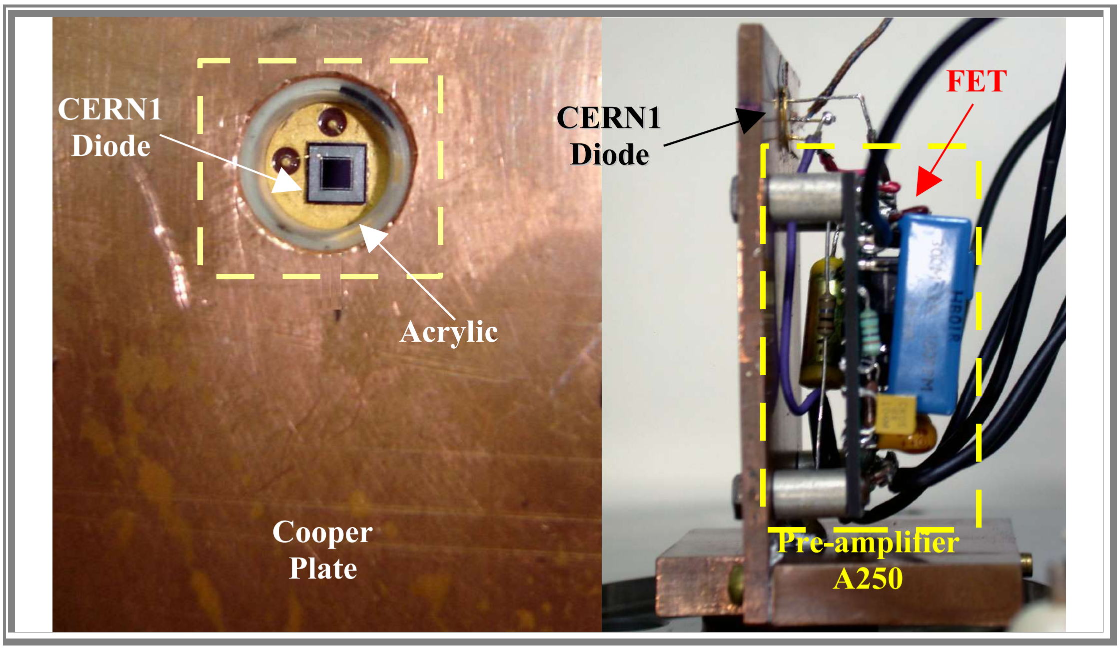

Figure 1. The diode and the tailor made preamplifier (A250) mounted on a cooper plate rivet to the vacuum chamber's cover.

3. RESULTS AND DISCUSSION

In order to study the bias voltage influence on the alpha pulse height distribution, it was recorded several spectra at room temperature with the source placed at 2.0 cm from the diode. The best result obtained, with the diode polarized at 60 V and 1 μs time constant, is depicted in Fig.2. Although the energy resolution obtained (FWHM = 18. 8 keV) for the 5485.6 MeV alpha particles from ^{241}Am was comparable to ordinary silicon barrier detectors, it was evidenced some satellite peaks (SP) developed at somewhat lower energies than the main peaks in the spectrum.

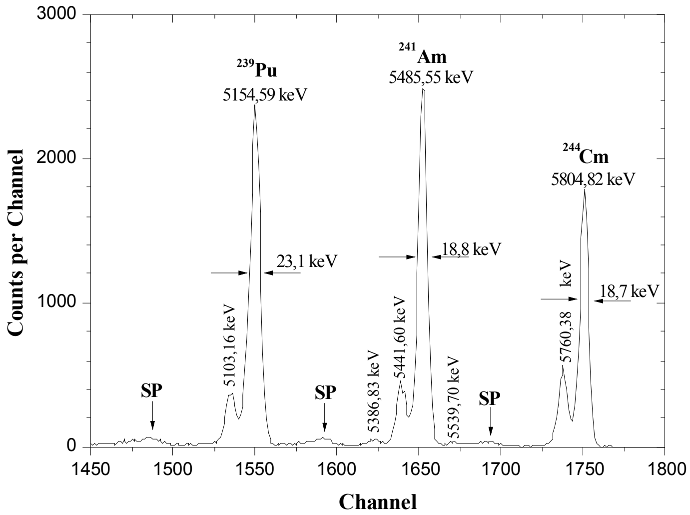

Figure 2. ^{239}Pu, ^{241}Am and ^{244}Cm pulse height distribution obtained with the CERN diode polarized at 60 V. First guard-ring grounded and 1 μs time constant.

Since this pulse distribution was obtained without any diode collimation, the origin of these satellite peaks was thought to be due to the events that occurred in the device's border. To verify this hypothesis, it was used a Teflon collimator (1 mm of diameter) placed at 2 mm from the diode. The spectra recorded with and without collimator are presented in a logarithmic scale (Fig.3) to evidence all satellite peaks, independently of its relative intensity.

The comparison between these spectra, both obtained at the same experimental conditions, showed that the use of a collimator leads to a significant reduction in the satellite peaks intensities, mainly for those located in the low energy part of the spectra. However, it was observed a weak collimation influence on the satellite peaks nearest the main alpha peaks in the spectra.

To verify if these high energy satellite peaks could be associated with the charge induction by the first grounded guard ring, it was changed the potential distribution among the ten guard rings, leaving all of them floating. The spectrum recorded at this condition with the diode collimated is showed in Fig. 4 with that obtained with the first guard ring grounded. It is evidenced the reduction in both the amplitudes and the intensities of the satellite peaks in the high energy part of these spectra when the guard rings were left floating. Conversely, it was not observed any difference in the low energy satellite peaks registered with the first guard ring grounded or at a floating potential.

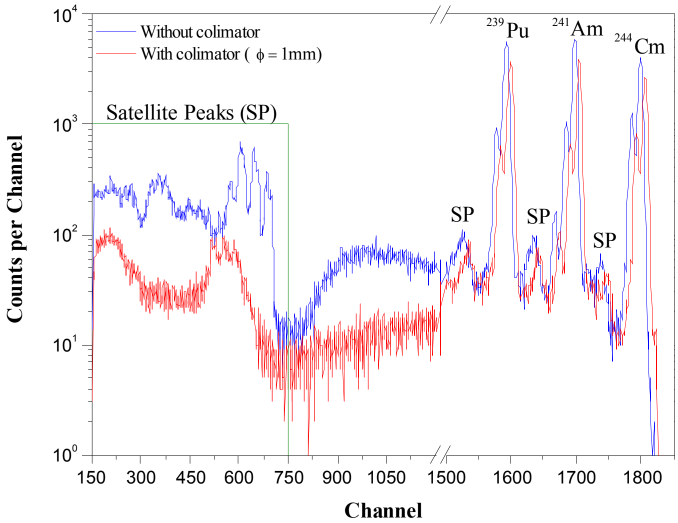

Figure 3. Alpha energy spectra of ^{239}Pu, ^{241}Am and ^{244}Cm obtained with and without the diode collimation. First guard ring grounded, V = 60 V and 1 μs time constant.

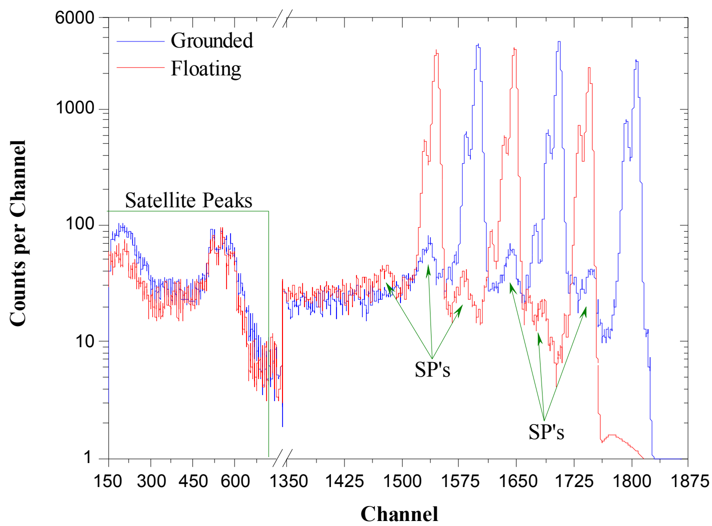

Figure 4. Pulse height distributions of alpha particles from a mixed source obtained with both the first guard ring of the diode grounded and floating.

As a consequence, one should conclude that the high and the low energy satellite peaks are due to the induced charge on the signal electrode by the first and second guard rings, respectively. Besides, the charge induction phenomenon depends on the potential distribution among the guard rings and is less important when they are floating.

4. CONCLUSIONS

Despite of the satellite peaks observed in the alpha particle spectra, the good energy resolution obtained (FWHM = 18. 8 keV for the 5485.6 MeV line of ^{241}Am) has shown that this diode has good performance for alpha particle spectrometry.

It was also demonstrated that the multi guard rings structure increases the edge effects responsible for the satellite peaks generation. Indeed, through the use of a diode collimator, it was possible to conclude that these peaks were due to the induced charge on the signal electrodes mainly by the first and the second guard rings. As one could expect, the induced charge on the p+ side of the diode was affected by the guard rings potential distribution and is less important when they are kept floating.

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