Manufactured Silicon Diode used as an Internal Conversion Electrons Detector

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Received on 29 October, 2003

In this work we have studied the direct detection and spectrometric capabilities for internal conversion electrons of an ion-implanted diode, developed in the framework of R&D programs at CERN, envisaging its use in an electron-gamma coincidence system for nuclear parameters measurements. The best energy resolution obtained until now, 12.6 keV (FWHM) for the ^{133}Ba 320.32 keV electron emission, is sufficiently good to justify the use of this diode for spectrometry of low energy electrons.

1 Introduction

Although silicon diodes have been mainly used for heavy charged particle spectrometry, their application as detectors of low energy electrons has increased in the last years [1-13] due to the simplicity of their use, associated with the fairly good energy resolution. Our previous results [14], obtained with a low-cost PIN photodiode of type SFH00206 (Siemens), encouraged us to study the direct detection capabilities of one special silicon diode for internal conversion electrons, envisaging its use in an electron-gamma coincidence system for nuclear parameters measurements. The device under investigation, an ion-implanted diode (Al/p$^+$/n/n$^+$/Al) developed in the framework of R&D programs for the future CMS experiment at Large Hadron Collider (LHC), bears excellent timing properties and high radiation hardness that fulfill the requirements from this accelerator environment. In this paper, the preliminary results obtained with this diode (referred as CERN diode) for the detection and spectrometry of internal conversion electrons from ^{133}Ba are described. The effect of the reverse bias on the energy resolution was studied and has shown a value of 12.6 keV (FWHM) for the ^{133}Ba 320 keV electron emission when the diode was biased with 40 V, at a temperature of 293 K.

2 Experimental Setup

The diode used in this work has an active area of 2.5 mm^2 and the resistivity of the substrate is about 5 kΩ.cm. The diode's electric contacts were made at LME/USP, as well as the dynamic measurements of its capacitance and leakage current. Figs 1 and 2 show the leakage current and capacitance of the diode as a function of the reverse bias voltage, respectively. Assuming that this diode is similar to a plane capacitor, we calculated its depletion depth-voltage characteristic, which is represented in Fig. 3. As one could conclude from these results, the maximum thickness of the depletion zone is about 170 μm. In order to use this diode as a detector, it was placed inside a stainless steel vacuum chamber and directly connected to a charge sensitive amplifier based on an integrated circuit A250 from Amptek. This circuit, originally projected for low energy X-rays, was slightly modified to match the characteristic of higher charge per pulse associated with charged particles. The pulses from the A250 were shaped and amplified by a linear amplifier (Ortec 572, shaping time = 2 μs) and fed to a multichannel analyzer (Ortec Spectrum Ace 8k).

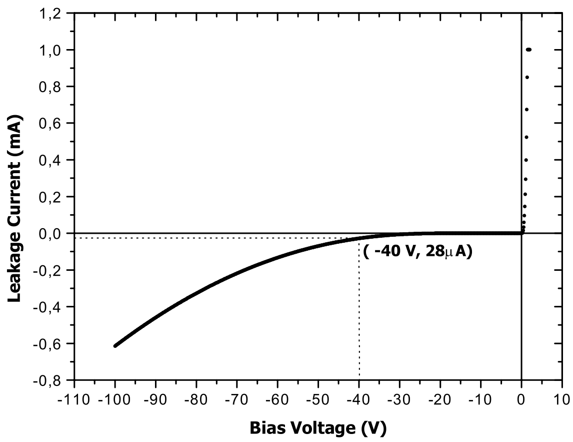

Figure 1. Leakage current of the CERN diode as a function of bias voltage.

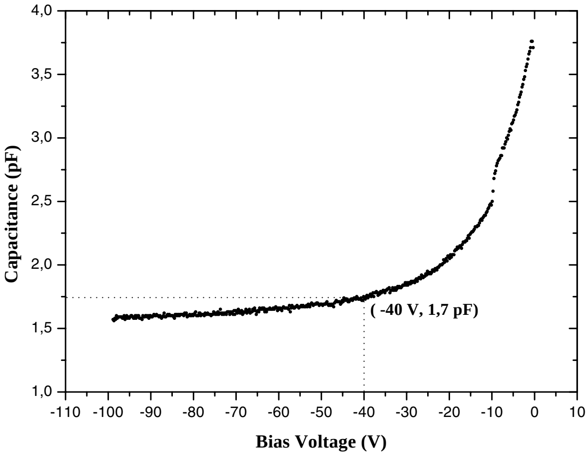

Figure 2. Capacitance of the CERN diode versus bias voltage.

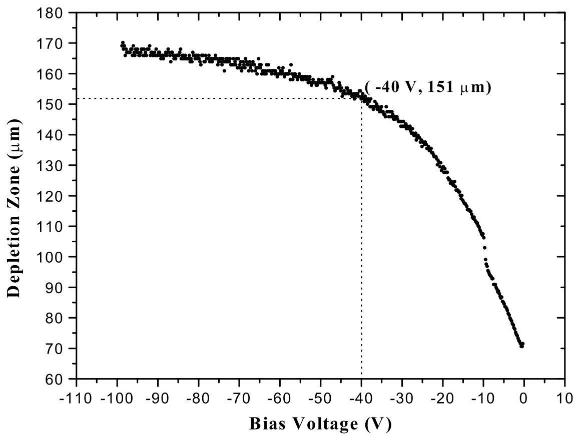

Figure 3. Depletion zone thickness of CERN diode as a function of bias voltage.

3 Results

The response of the diode for internal conversion electrons was studied by using a ^{133}Ba source covered with a thin (about 2 μm) makrofol foil. The radioactive material was deposited on a 0.4 mm polyethylene disk and placed at 2 cm from the detector in a stainless steel vacuum chamber under a pressure of 10^{-5} Torr. The spectrometric performance of the diode for internal conversion electrons was studied recording several energy spectra under different experimental conditions at room temperature. Until now, the best result was obtained with 40V reverse diode's voltage which is presented in the Figs 4 and 5. The low energy part of the spectrum (Fig. 4) shows the lines corresponding to the electrons of 45.01 and from 73.90 up to 80.98 keV (not resolved) with a poor energy resolution due to the energy loss in the makrofol foil and the diode dead layer, superposed to the electronic noise. In the high-energy part of the spectrum (Fig. 5), one can easily identify the electrons lines of 124.63 (FWHM = 9.3 keV), 154.90, 187.25, 240.41, 266.87, 320.32 (FWHM = 12.6 keV) and 347.87 keV energy.

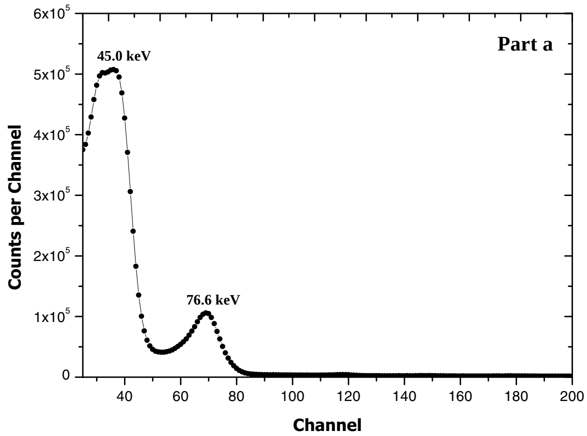

Figure 4. Internal conversion eletrons spectrum from ^{133}Ba (part. a).

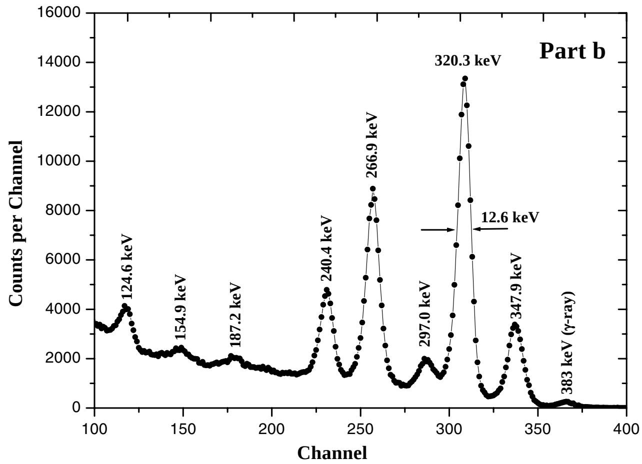

Figure 5. Internal conversion eletrons spectrum from ^{133}Ba (part. b).

4 Conclusion

The preliminary results showed that the energy resolutions obtained for internal conversion electrons using this CERN diode are sufficiently good to justify its use for charged particle spectrometry. However, since the broadening of the lines can be attributed, besides the contribution of the preamplifier electronic noise, to both the energy loss in the diode dead layer and in the makrofol covering the source, it will be possible to improve the energy resolution utilizing a cooling system and an open radioactive source. These studies are under way.

Acknowledgments

The authors would like to thank IPEN-CNEN/SP, CNPq and FAPESP for financial support during this work. One of us, A. A. S. Corrêa, thanks FAPESP for the award of a scholarship.

References

[1] L. Bellucci,Nucl. Instrum. and Meth. A**462**, 243 (2001).

[2] M. Pauluzzi, Nucl. Instrum. and Meth. A**473**, 67 (2001).

[3] F. Tosello, Nucl. Instrum. and Meth. A**473**, 210 (2001).

[4] Y.S. Tsyganov et al, Nucl. Instrum. and Meth. A**477**, 406 (2002).

[5] P. Sievers, Nucl. Instrum. and Meth. A**485**, 23 (2002).

[6] G. Lutz et al, Nucl. Instrum. and Meth. A**461**, 393 (2001).

[7] E.Steiner et al , Nucl. Instrum. and Meth. A**339**, 102 (1994).

[8] E. do Couto e Silva, Nucl. Instrum. and Meth. A**473**, 107 (2001).

[9] E. Steinbauer et al, Nucl. Instrum. and Meth. B**85**, 642 (1994).

[10] G. Lindström et al, Nucl. Instrum. and Meth. A**426**, 1 (1999).

[11] T. Kamae, Nucl. Instrum. and Meth. A**436**, 297 (1999).

[12] A. Khodin et al, Nucl. Instrum. and Meth. A**465**, 253 (2001).

[13] T. Wichert and M. Deicher, Nucl. Instrum. and Meth. B**693**, 327 (2001).

[14] C.C. Bueno, J.A.C. Gonçalves, and M.D.S. Santos, Nucl. Instrum. and Meth, A**371**, 460 (1996).