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LOW-ENERGY INTERNAL CONVERSION ELECTRONS SPECTROMETRY WITH A SILICON DIODE

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ABSTRACT

In this paper the preliminary results obtained with a PIN photodiode (SFH00206) for the detection and spectrometry of internal conversion electrons from ^{57}Co, ^{109}Cd and ^{133}Ba radioactive sources are described. The effect of the reverse bias on the energy resolution was studied and has shown a value of 2.8 keV (FWHM) for the ^{57}Co 129.36 keV electron emission, when the diode was biased with 20 V at a temperature of 22 ºC. The obtained energy resolution can be attributed to both the energy loss in the diode dead layer and in the makrofol covering of the sources, besides the contribution of the preamplifier electronic noise. Nevertheless, the energy resolutions measured are sufficiently good to justify the use of this diode for detection and spectrometry of internal conversion electrons.

1. INTRODUCTION

Electron spectroscopy of high energy resolution has been typically carried out with Si(Li) detectors [1]. Indeed, the low atomic number value of silicon assures that fewer electrons will backscatter from the sensitive volume of the detector without depositing their full energy. Conversely, since these detectors must be cooled to liquid nitrogen temperature, they are usually enclosed within a vacuum cryostat which entrance window is responsible for an important energy straggling of incoming low energy electrons. These drawbacks and the high cost of Si(Li) detectors, have pushed a big effort to develop spectrometric systems based on other semiconductor devices, suitable for room temperature operation [2,3]. In this context, the application of silicon diodes as detectors of low energy charged particles and electromagnetic radiations has increased in the last years, due to the simplicity of their use associated with the fairly good energy resolution that can be achieved, even at room temperature.

Recent good spectrometry results obtained in our laboratory [4] with a cheap PIN photodiode for detection of low-energy gamma and X-rays led us to investigate its response for internal conversion electron spectrometry envisaging its use in an electron-gamma coincidence system for nuclear parameters measurements. In this paper the preliminary results obtained with this diode for the detection and spectrometry of internal conversion electrons from ^{57}Co, ^{109}Cd and ^{133}Ba radioactive sources are described. The effect of the reverse bias on the energy resolution was studied and has shown a value of 6.2 keV (FWHM) for the ^{57}Co 129.36 keV electron emission, when the diode was biased with 20 V at a temperature of 22 ºC.

2. EXPERIMENTAL SETUP

The device used in this work was a PIN photodiode, SFH00206, with an active area of 7.34 mm^2, capacity of 72 pF (at 0 V) and leakage current smaller than 5 nA. However, in spite of these good properties, it was covered with a plastic layer of 1.2 mm, which would certainly be an important source of the energy resolution deterioration. To avoid it, the manufacturer (Siemens) free supplied us with a disencapsulated diode which was mounted on a gold TO (transistor outline) to make the electrical connections of the back (n^+) and front (p^+) sides of the device.

The current-voltage characteristics of the detector is presented in Fig. 1, which showed a typical diode behaviour with leakage currents increasing from 0.7 to 5.2 nA, at a voltage range between 0 V and 30 V. The dynamic diode capacitances, measured at a frequency of 10 kHz by means of a home-made capacitance system, decrease with the polarization bias as a result of the depletion layer growth. From Fig. 2, one should observe that at voltages above approximately 20 V the fully depleted configuration is achieved, which means that the width of the depletion region of the diode reaches about 75 μm.

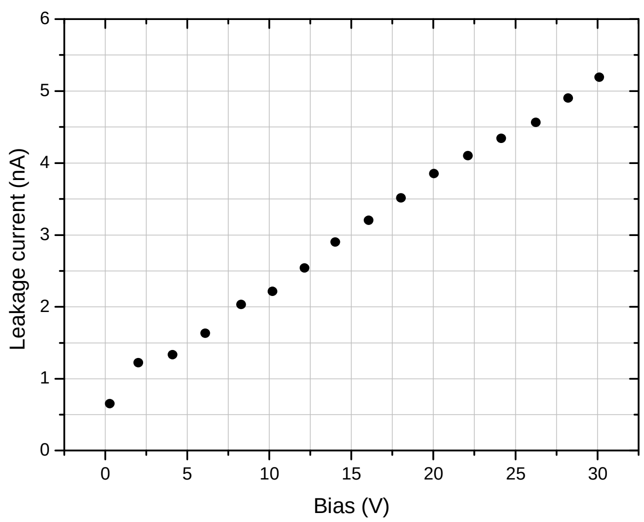

Figure 1. Current-voltage characteristics of the diode SFH00206.

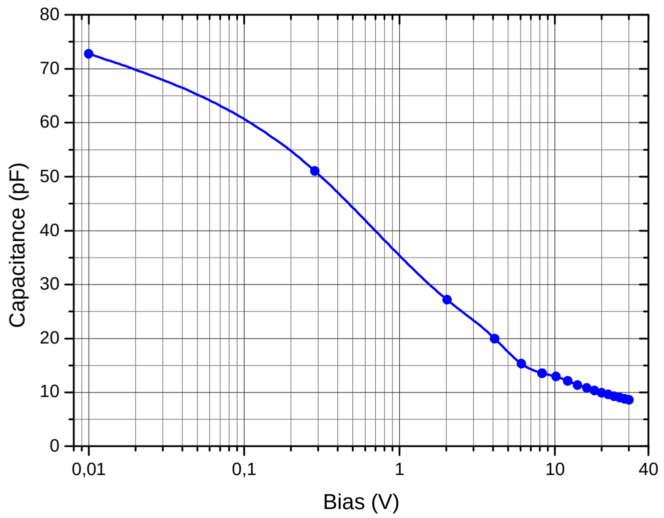

Figure 2. Dynamic SFH00206 PIN diode capacitances, measured at a frequency of 10 kHz.

In order to use this diode as a detector, it was connected (DC coupling) to a field effect transistor (FET) in the first stage of a charge sensitive pre-amplifier based on the hybrid circuit A250 (Amptek). This assembly was placed inside a vacuum chamber and kept at 2.0 cm from the ^{57}Co, ^{109}Cd and ^{133}Ba radioactive sources (all of them deposited on a 0.4 mm thick polyethylene disk and covered with a 2 μm makrofol foil). The pulses from the pre-amplifier were shaped and amplified by a linear amplifier (Ortec 572) and finally fed to a multi channel analyzer.

3. RESULTS

The spectrometric performance of the diode for internal conversion electrons was studied recording several energy spectra under a pressure of 10^{-5} Torr and at room temperature. The influence of the bias voltage on the energy resolution was first investigated and the results obtained for the 114.95 keV internal conversion electrons from ^{57}Co is presented in Fig. 3. The poor energy resolution obtained at low applied voltages is due to both the electronic noise of the system and the partial charge collection generated in the depletion layer of the diode. Conversely, for higher bias voltages, the increase of the diode leakage current worsens the signal-electronic noise ratio and, consequently, the energy resolutions that can be achieved. So, one should expect that there is one bias voltage value for which the amount of noise is minimum and, therefore, the best energy resolution obtained. In our measurements this occurs at 20 V, as can be seen in Fig. 4, 5 e 6, which display the best pulse height distributions from ^{57}Co, ^{109}Cd and ^{133}Ba radionuclides, respectively.

The energy spectrum of ^{57}Co (Fig. 4) shows clearly the peaks related to electrons of 114.95 and 129.36 keV with energy resolutions (FWHM) of 2.9 keV and 2.8 keV, respectively. Despite of being superimposed on the electronic noise tail, it is also observed the photopeak correspondent to the 14.41 keV X-rays from ^{57}Fe. Indeed, since the mechanism of pair electron-hole production is the same for photons and electrons, it is possible to register both

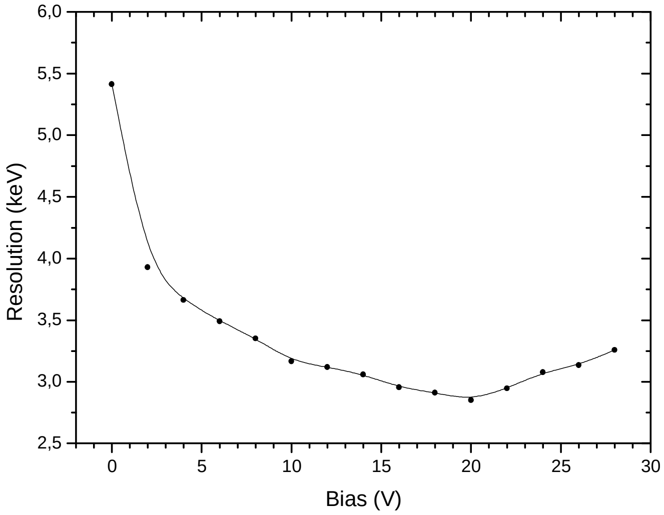

Figure 3. Energy resolution as a function of bias voltage for 114.95 keV internal conversion electrons from ^{57}Co.

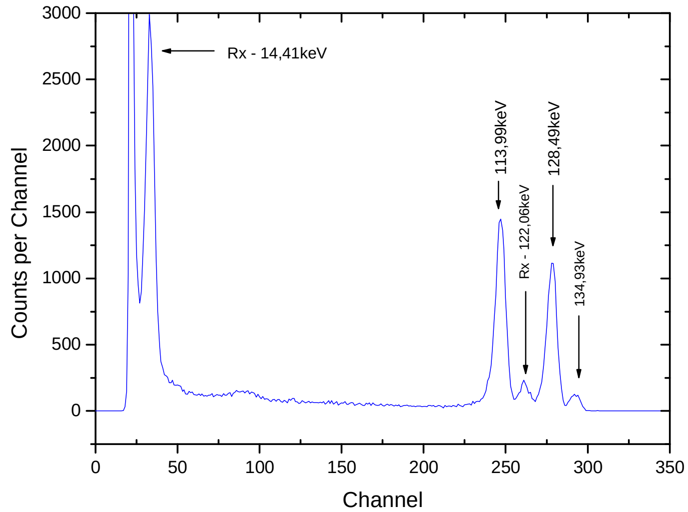

Figure 4. Energy spectrum of ^{57}Co (bias = 20 V).

of them at the same experimental conditions. This fact is also observed in Fig. 5 which displays the spectrum of ^{109}Cd with the two internal conversion lines (of 59.98 keV and 82.56 keV) and the X-rays of 22 keV. The energy resolutions obtained are slightly worse than those obtained for the electrons from ^{57}Co due to the energy losses in both the makrofol foil and the dead layer of the diode, which is more important for lower energy incoming electrons.

The best ^{133}Ba energy spectrum is presented in Fig. 6, which displays the lines corresponding to electrons with energies from approximately 40 keV to 350 keV. It is noted a significant

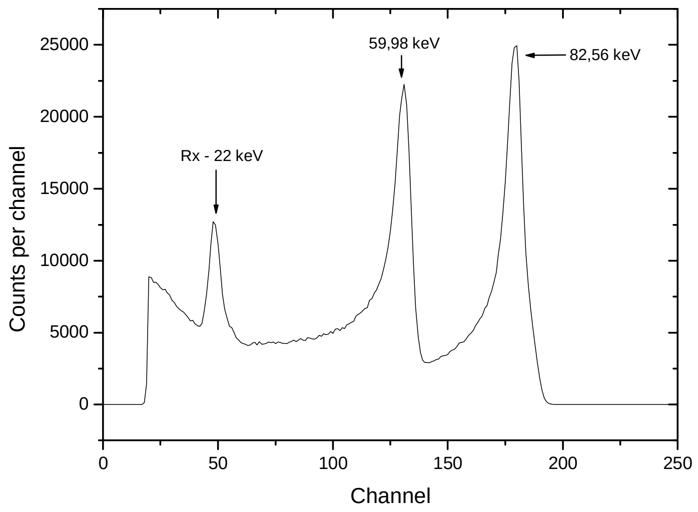

Figure 5. Energy spectrum of ^{109}Cd (bias = 20 V).

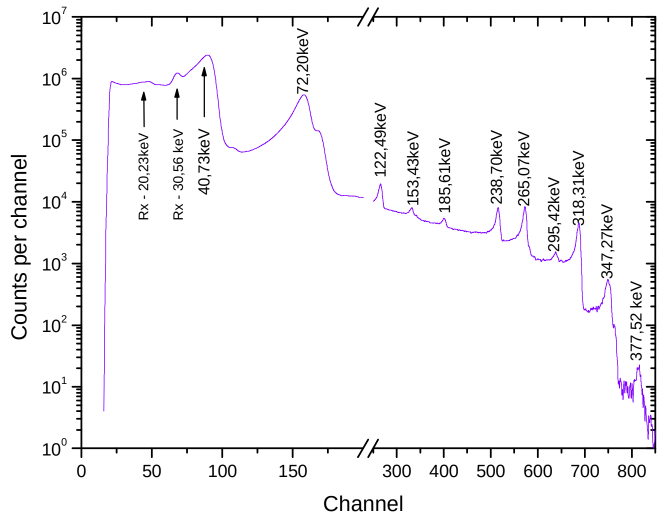

Figure 6. Energy spectrum of ^{133}Ba (bias = 20 V).

higher energy electrons backscattering tail responsible for the reduction of the detector efficiency for the total absorption of the electron energy. In fact, the broadening of the electron lines is partly due to both the energy loss in the diode dead layer and to the backscattered electrons leaving the diode without fully depositing their energy. However, the energy resolution obtained (FWHM = 2.8 keV for the 185.61 keV electrons) is good enough to allow the use of this diode for electron spectroscopy.

4. CONCLUSIONS

It has been shown that the low-cost commercial PIN photodiode, type SFH00206, is appropriate for detection and spectrometry of electrons in the energy range of 40 keV to 350 keV. In the low energy region, the largest contribution for the resolution is due to both the preamplifier electronic noise and the energy loss in the diode dead layer and in the makrofol covering of the sources. For high energy electrons, the deterioration of the obtained energy resolution can be attributed to the backscattering phenomena due to the small thickness of the diode depletion layer. Nevertheless, the energy resolutions measured showed that this diode can be used for detection and spectrometry of internal conversion electrons and is a low budget alternative, good enough for many applications.

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