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COUNT RATE EFFECT ON THE RESPONSE OF A LOW-COST PIN DIODE FOR ELECTRON SPECTROMETRY

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ABSTRACT

The response of a low-cost Si photodiode model BPX 65 for low-energy electron spectrometry is investigated envisaging its use in measurements of electron multiple elastic scattering. The electron beam with energy between 10-100 keV is delivered by the gun of the Racetrack Microtron at Instituto de Física, Universidade de São Paulo, with an energy dispersion less than 0.5 keV. The energy resolution achieved was less than 3.5 keV, limited mainly by noise from the electronic acquisition chain. For count rates between 20 and 5500 counts/s, the variation on the centroid of electron peak was smaller than 0.4% throughout the energy range. Therefore, the BPX 65 is suitable for electron spectrometry.

1. INTRODUCTION

Commercial silicon PIN photodiodes are an attractive alternative as low-cost detectors. For decades, these devices have been applied successfully in the detection and spectrometry of internal conversion electrons, low-energy photons and alpha particles, thanks to their simplicity of use, good energy resolution and low cost [1-11]. Typical energy resolution, in terms of full width at half maximum (FWHM), is 1.8 – 4.5 keV for internal conversion electrons and photons and 11.0 – 16. 7 keV for alpha particles [4, 6, 10]. However, they are used in electron accelerators only for to X-ray detection [12], motivating the present investigation on electron beam spectrometry with commercial PIN photodiodes.

The chosen device is a Si PIN photodiode, model BPX65 supplied by Osram® with planar geometry. This photodiode was so far used only as radiation dosimeter either with gamma-rays or ions [13, 14]. Its dead layer was estimated by Jaksic et al. [13] as being 300 nm, encouraging this study on its application as electron spectrometer. In this paper, the preliminary results obtained with this low-cost photodiode for the electron spectrometry in the 40 – 100 keV energy range using electrons from the São Paulo Racetrack Microtron Accelerator is presented. The effect of the count rate on the centroid of the full-energy peak is also assessed.

2. MATERIALS AND METHODS

The BPX 65 is a commercial PIN (p-type – intrinsic – n-type) photodiode with capacitance of 11 pF (at 0V) and an active area of 1 x 1 mm^2. This device is encapsulated in a TO-18 metal can package, whose optical window has been removed to allow electron detection. From capacitance measurements, the operational bias of BPX 65 has been chosen as 18 V, which correspond to a thickness of the depletion layer of 60 ± 3 μm.

The windowless photodiode has been placed inside a stainless-steel vacuum chamber kept under a pressure of 7 mPa. The BPX65 has been directly connected to a charge sensitive pre-amplifier (model 2004 by Canberra®). Its output pulses have been shaped and amplified by a linear amplifier (model 572 by Ortec®), whose shaping time has been set at 2 μs and the gain at 800, and fed to a multichannel analyzer (model 927 Aspec by Ortec®).

The electron beam from the Racetrack Microtron at Instituto de Física, Universidade de São Paulo, with energy ranging from 10 to 100 keV, is delivered to the irradiation chamber. The beam current has been adjusted in order to obtain different count rates for 40, 60 and 100 keV.

The BPX 65 has been positioned perpendicularly to the electron beam at 0° inside the irradiation chamber. An Al collimator with an aperture of 0.5 mm in diameter and a thickness of 0.3 mm is placed in front of the detector. From the acquired electron beam spectra, a background spectrum, measured by deviating the electron beam, was subtracted.

In order to calibrate the spectrometric system, photons and electrons have been used. Under 60 keV, photons from radioactive sources have been the calibration references, since the energy loss by particles in the dead layer of the diode is more significant at low energies. Spectra of ^{241}Am, ^{133}Ba and ^{57}Co radioactive sources have been acquired at room temperature, placing a 0.5-mm thick Al foil between the BPX65 diode and the sources to guarantee the detection of photons only. All gamma-ray emissions under 60 keV from these radioactive sources have been used for the calibration curve (from 14.4 keV to 59.5 keV). For energies above 60 keV, the nominal voltage of the electron gun has been used, which presents an uncertainty of 500 eV estimated by comparing the nominal value with experimental data determined from the maximum energy of bremsstrahlung spectra from different targets. This technique was described by Fernández-Varea et al. [15].

3. RESULTS

The energy spectra from electron beams of 40, 60 and 100 keV are presented in Figures 1, 2 and 3, respectively. The different colors correspond to different count rates. The counts in all spectra have been normalized to the live time (acquisition time minus dead time) of the spectrum with lowest count rate.

The full width at half maximum (FWHM) of the full-energy peaks is less than 3.5 keV, limited mainly by electronic noise from the acquisition chain, since the resolution of a pulser is 3.3 keV.

Peaks can be seen for count rate over 50 counts/s placed in a region around two times the energy of the electron beam and thus the full-energy peak. These peaks are due to pile-up events, where two pulses partly or completely overlap in time, even with the pile-up rejection circuit turned on.

There is a low-energy continuous component at energies below the full-energy peak. According to Damkjaer [16], this region is formed by electron backscattering and bremsstrahlung emission. In our case, the latter is responsible for less than 0.03% of the total energy loss [17]. Therefore, these counts should only arise from backscattered electrons.

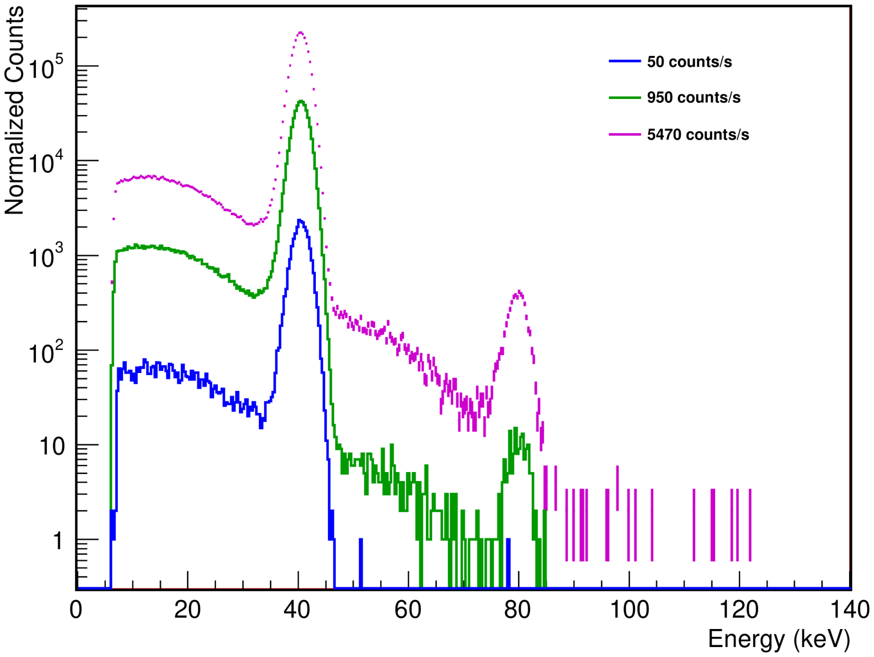

Figure 1: Energy spectrum from a 40-keV electron beam for different count rates.

For count rates between 20 and 5500 counts/s, the variation on the centroid of the electron peak was lower than 0.4% throughout the energy range, as presented in Figure 4. Nevertheless, the determination of full-energy peak centroid in the presence of pile-up peak is rather difficult. Thus, it is likely that this difference is mainly due to the pile-up rather than the different count rates. For this reason, the future application of the BPX 65 photodiode for electron spectrometry will be conducted for low count rates.

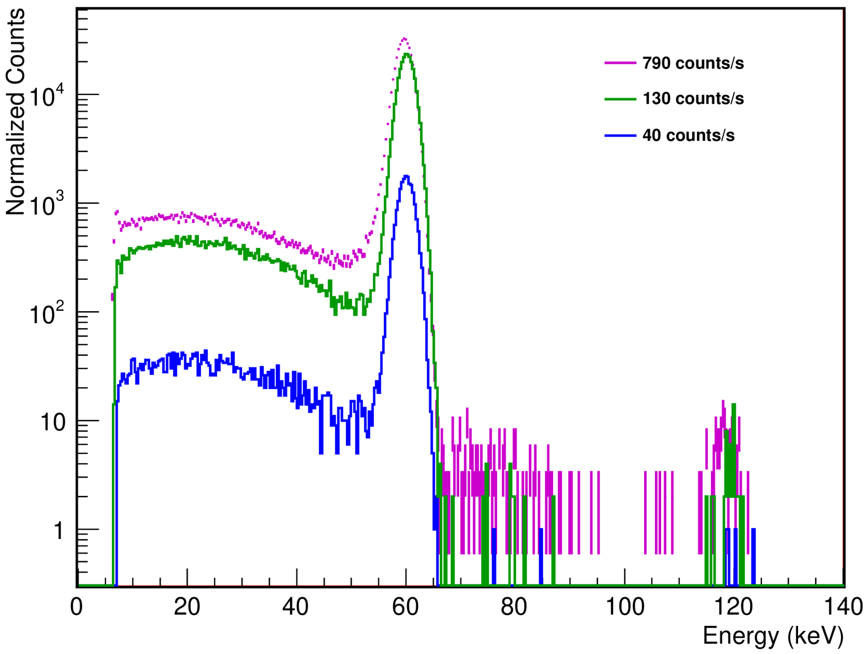

Figure 2: Energy spectrum from a 60-keV electron beam for different count rates.

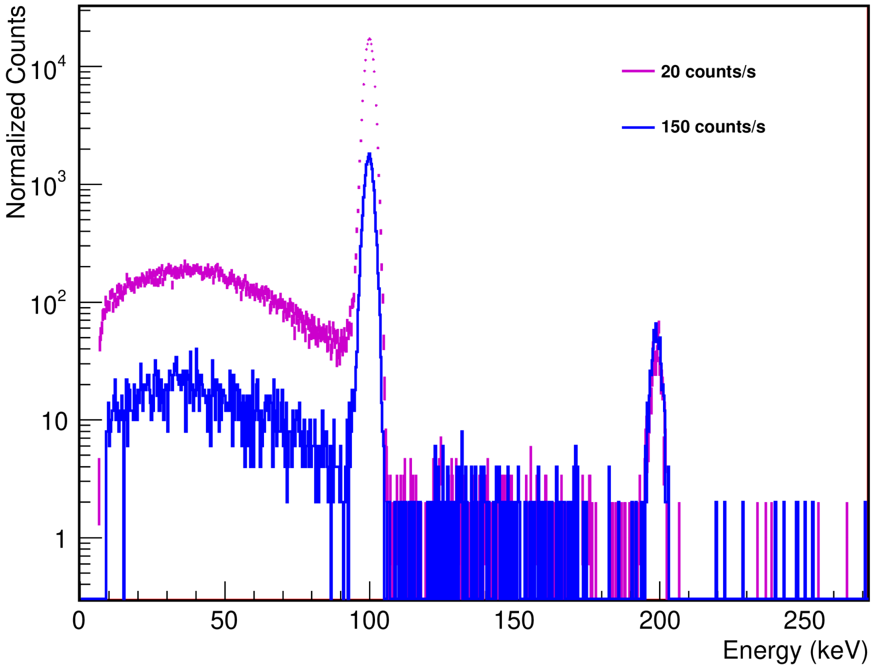

Figure 3: Energy spectrum from a 100-keV electron beam for different count rates.

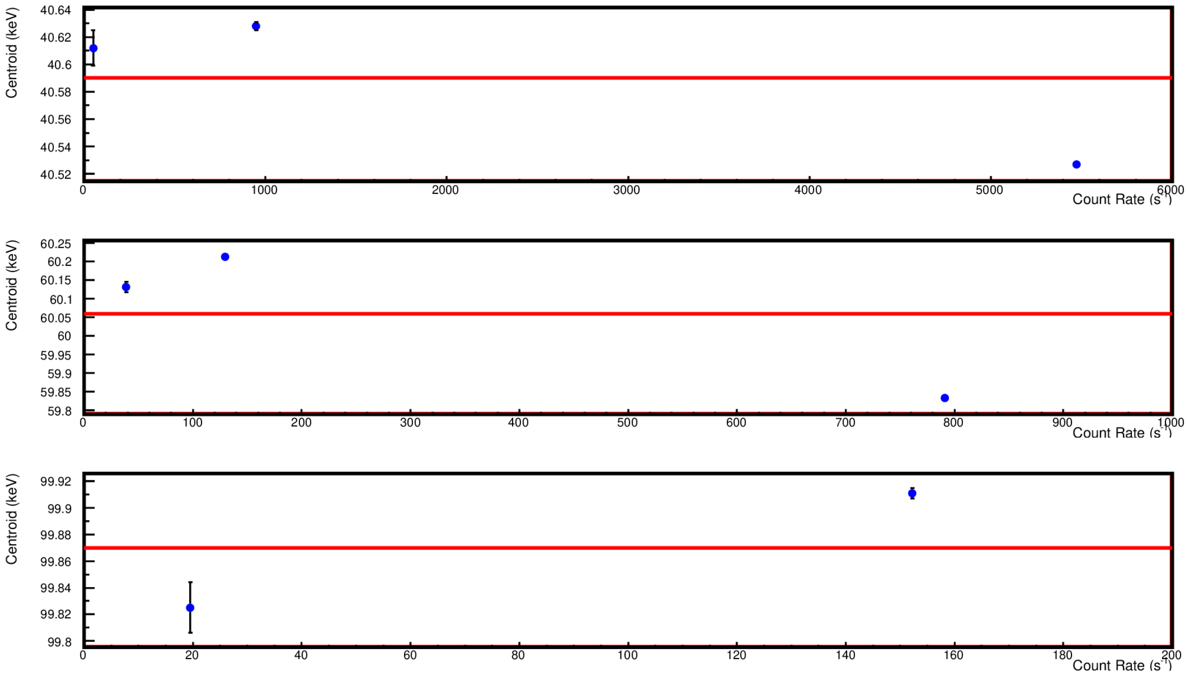

Figure 4: Peak centroid as function of the count rate. The red lines represent the mean value.

4. CONCLUSIONS

The performance of the BPX 65 as an electron detector for energies between 40 and 100 keV have been investigated. Despite the low efficiency, the energy resolution is less than 3.5 keV, quite comparable to other commercial PIN photodiodes operated at room temperature. The main limitation for its resolution in the employed setup is noise from the electronic chain (3.3 keV). No appreciable shift in the centroid of the full-energy peak is observed with incresing count rate up to 5500 counts/s, being always less than 0.4 %. Nevertheless, the presence of pile-up peak even with the pile-up rejection circuit turned on indicate that, when precision is needed, the BPX 65 photodiode should be exposed to low count rates.

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