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INFLUENCE OF THE DEAD-ZONE THICKNESS ON A PIN DIODE RESPONSE FOR α SPECTROMETRY

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ABSTRACT

In this work, it has been investigated the influence of the dead-zone thickness on a silicon photodiode (Siemens SFH00206) response for alpha spectrometry envisaging its future application for measurement of isotopic ratios of alpha emitters. The technique used was to vary the angle of incidence of alpha particles from a mixed nuclide source of ^{239}Pu, ^{241}Am and ^{244}Cm and record the pulse height distribution. The directional dependence of the diode performance for alpha spectrometry was confirmed by the peak shift and broadening observed in the spectra recorded at angles of incidence ranging from 0º (i.e. perpendicular to the diode surface) to 60º.

1. INTRODUCTION

Semiconductor detectors are widely used for spectrometric purposes in a variety of both research and applied physics experiments [1-3]. Their unsurpassed virtue as the achievable high energy resolution even operating at room temperature has made them the ideal choice for charged particle spectrometry. However, depending on the detector design and the polarization voltage, there is a dead layer through which the incident radiation must pass before reaching the active region of the device. Mainly for charged particles, the energy loss in this insensitive zone detracts from the energy resolution and imposes constraints on high-resolution charged particle spectrometry. Since the energy loss depends on the total path length traversed and, consequently, on the incidence angle of the incoming radiation, one should expect an angular dependence of both energy resolution and pulse height distribution of monoenergetic charged particle radiation.

In this work, it has been investigated the influence of the dead-zone thickness on a silicon photodiode (Siemens SFH00206) response for alpha spectrometry envisaging its future application for measurement of isotopic ratios of alpha emitters. The technique used was to vary the angle of incidence of alpha particles from a mixed nuclide source of ^{239}Pu, ^{241}Am and ^{244}Cm and record the pulse height distribution [4,5]. The directional dependence of the diode performance for alpha spectrometry was confirmed by the peak shift and broadening observed in the spectra recorded at angles of incidence ranging from 0º (i.e. perpendicular to the diode surface) to 60º.

2. EXPERIMENTAL SETUP

The device used in this work, a PIN photodiode (SFH00206), was free supplied by Siemens without the original plastic cover as well as its electrical leads. To make the connections of both signal (p) and polarization (n) electrodes, the PIN diode was fixed on a gold TO (Transistor Outline) at Laboratório de Microeletrônica da Escola Politécnica – USP (University of São Paulo). The electrical characterization of the photodiode was performed through measurements of leakage current and capacitance as a function of the reverse bias voltage. With the diode fully depleted (V = 20 V), the thickness of the depletion region (75 μm) was estimated from the diode capacitance measurements [2].

In order to use this diode as a detector, it was placed inside of a stainless steel vacuum chamber (under a pressure of 10^{-5} Torr) and directly connected to a charge sensitive preamplifier based on an integrated circuit A250 from Amptek. The pulses from the A250 were shaped and amplified by a linear amplifier (Ortec 572) and fed to a multi channel analyzer. The radioactive source utilized was a mixed alpha emitters nuclides of ^{239}Pu, ^{241}Am and ^{244}Cm, deposited on a stainless steel disk, placed at 3.0 cm from the detector.

Several energy spectra were recorded at incidence angles of the alpha particles from 0º up to 60º with the diode fully depleted (V = 24 V), at room temperature (20 ºC). The effects of the dead layer on the energy resolution and the total energy deposited in the active region of the detector were also studied.

3. RESULTS

The influence of the bias voltage on the diode spectrometric performance was studied with the alpha particles impinging perpendicularly upon the device surface. The energy resolution of the principal group of alpha particles from each ^{239}Pu, ^{241}Am and ^{244}Cm nuclides was measured as a function of the detector reverse voltage. The comparative energy resolution of the three radioactive isotopes is displayed in Fig. 1, which shows that, even without reverse bias, it is distinguished the main alpha group of each radionuclides. In this case, the poor energy resolution is due to the partial charge collection and the fairly large capacity (72 pF) of the device. On the other hand, an increase of the polarization voltage lessens the diode capacity and consequently, the electronic noise, which leads to improvements in energy resolution. Indeed, the best mixed alpha source spectrum, presented in Fig. 2, was recorded under a bias voltage of 24 V. The fine structure lines of each isotope can be clearly inferred with a very good energy resolution (e.g. FWHM = 16.2 keV for the 5.486 MeV alpha particles from ^{241}Am).

The effects of the dead layer thickness on the energy resolution and the total energy deposited in the active region of the detector were measured with angles of incidence ranging from 0º (normal incidence) to 60º. Fig. 3 shows the results obtained with the reverse voltage of 24 V and evidences both broadening and shift of the pulse height distribution peaks for alpha particles that were incident at oblique angles to the diode surface.

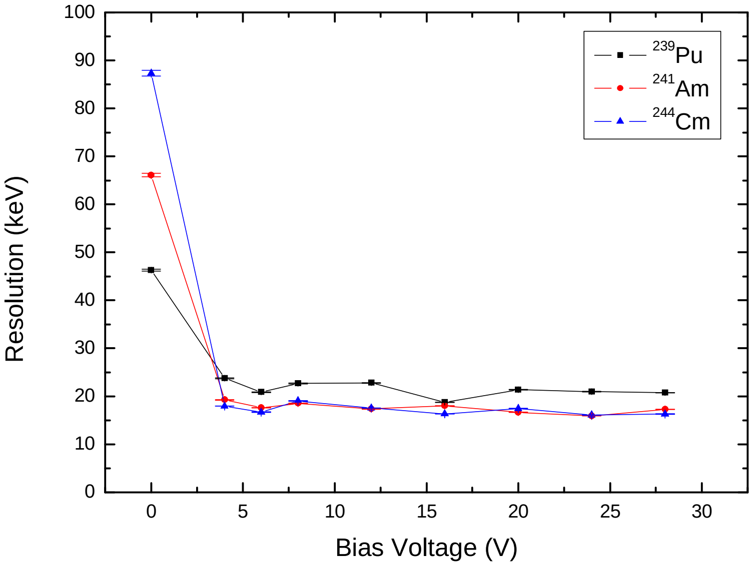

Figure 1. Energy resolution as a function of the detector reverse bias voltage.

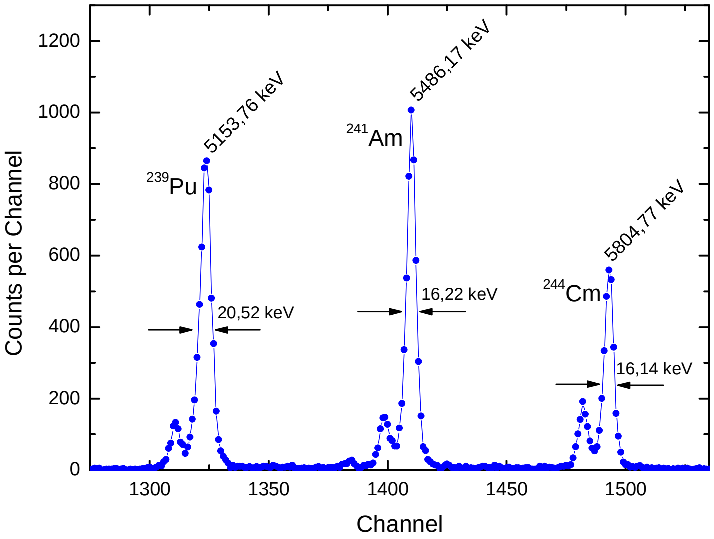

Figure 2. Best mixed alpha source spectrum.

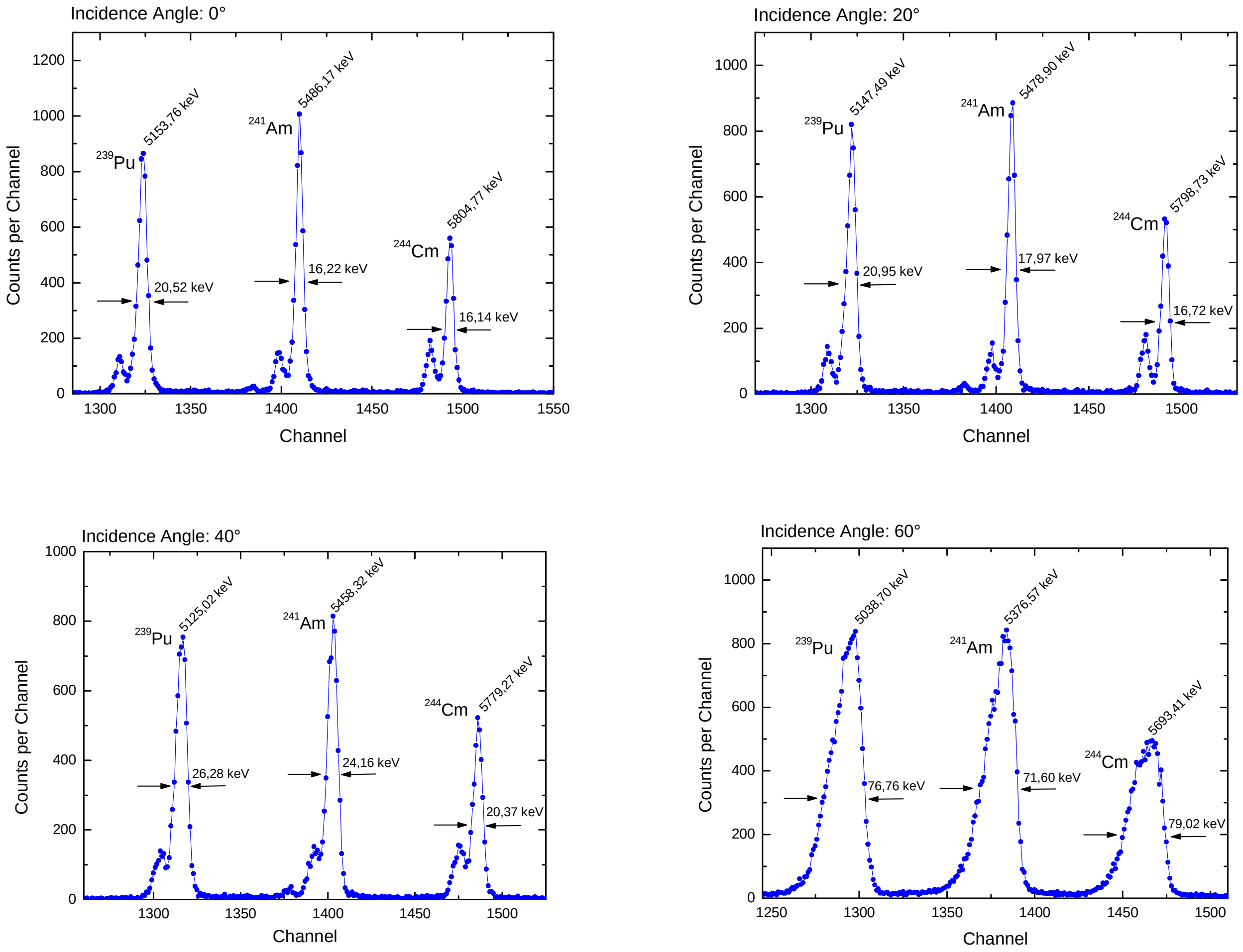

Figure 3. Mixed alpha source at different angles of incidence.

Indeed, in such conditions, the longer path length traversed by the alpha particles before reaching the sensitive volume of the detector is responsible for higher straggling and energy loss. These both effects detract from the energy resolution and are responsible for pulses shift from the full-energy peak at normal incidence to lower amplitudes in the spectra recorded at oblique angles to the diode surface. This behavior is confirmed by the results of the energy resolution as a function of the incidence angles of the main group of alpha particles from ^{239}Pu, ^{241}Am and ^{244}Cm nuclides presented in Fig. 4. Better results were obtained when alpha particles impinged the diode at near-normal incidence.

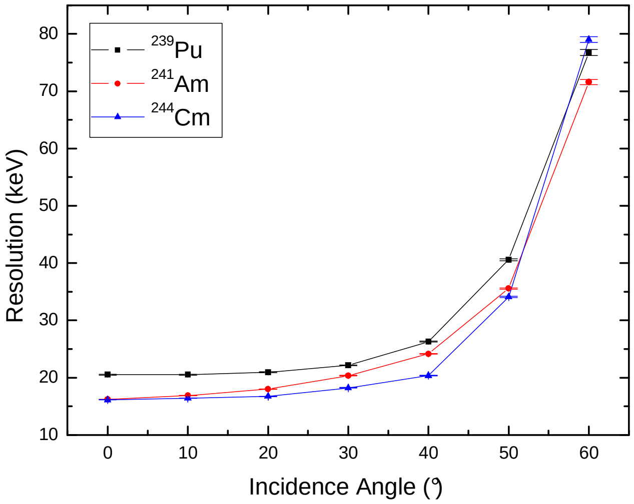

Figure 4. Energy resolution as a function of the incidence angles.

3. CONCLUSIONS

The spectrometric response of the SFH00206 photodiode has demonstrated that this device will certainly be a useful tool for charged particle spectrometry. Indeed, the best energy resolution achieved (FWHM) obtained (20.52 keV, 16.22 keV and 16.14 keV) for the main groups of alpha particles from ^{239}Pu, ^{241}Am and ^{244}Cm nuclides, respectively) is comparable to those attainable with ordinary silicon surface barrier detectors.

However, the influence of the dead zone thickness on the diode performance is clearly observed and, for spectrometric applications, it is obviously of advantage to restrict the incident alpha particles to near-normal incidence only.

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REFERENCES

1. C.C Bueno, J.A.C Gonçalves and M. D. S. Santos, “The performance of low-cost commercial photodiodes for charged particle and X-ray spectrometry”, *Nucl. Instrum. Methods Phys. Res.*, **v. A371**, pp. 460-464 (1996).

2. C.C Bueno, J.A.C Gonçalves, R. R. Magalhães and M. D. S. Santos, **“**Response of PIN diodes as room temperature photon detectors”, *Appl. Rad. And Isotopes* **61(6)**, pp.1343-7 (2004).
3. F. Hartmut and -W. Sandrozinski, “Applications of Silicon Detectors”, *IEEE Trans. on Nucl. Sci.*, **v. 48(4)**, pp. 933-940 (2001).
4. F. Camargo, “Fatores que Influenciam a Resolução em Energia na Espectrometria de Partículas Alfa com Diodos de Si”, MSc. thesis in http://www.teses.usp.br/teses/disponiveis/85/85131/tde-11052006-163022/ (2005).
5. Y. Akimoto, Y. Inoue and M. Minowa, “Measurement of the thickness of an insensitive surface layer of a PIN photodiode”, *Nucl. Instrum. Methods Phys. Res.*, **v. A557**, pp. 684-687 (2006).