Characterization of resistive anode position-sensitive silicon detector

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Introduction

Nuclear physics and particle physics experiments require position sensitive detectors (PSD) to determine the particle trajectories. Segmented detector like silicon micro-strip and pixel detectors are widely used for tracking. In some applications, where multiplicity and counting rates are not critical, continuous PSD are well suited. They have been used as position as well as *ΔE/E* detectors in particle identification experiments [1]. They have advantage of less front end electronics requirement as compared to segmented detectors.

In our present work, we have tested three continuous tetra-lateral types PSD. The detectors belong to the CATE setup of the RISING campaign at GSI [1]. Each detector has four positions and one energy signals. Charge sensitive preamplifiers (CSPA) were fabricated to extract all 15 signals. We have achieved position and energy resolution of ~ 2.5 mm (FWHM) and ~ 182 keV (FWHM) respectively, for 5.15 MeV alpha particles.

Detector design

The schematic of the detector is shown in the Fig. 1. Detector is square shaped with dimensions of 50 mm X 50 mm and 300 µm thick. Capacitance of the detector is ~ 1 nF.

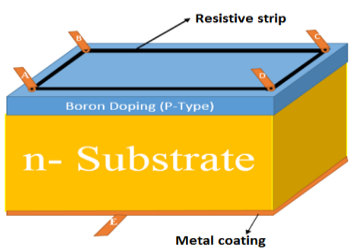

Fig. 1 Schematic diagram of tetra-lateral type PSD detector

The base material is a n-type silicon substrate onto which boron ions were implanted to make PN-junction and resistive layer. Additional, ion-implanted strip lines with a low resistance of 1 kΩ are also implanted near the edges for better position distortion performance [2]. The detector has a uniform metal coating on n-side of the detector Position signals were taken from the junction side and energy (*E*) from the ohmic side of the detector.

Detector assembly

Fig. 2 shows the rear view of the board consisting of all the three detectors and CSPAs. The CSPA circuit is inspired by earlier developed design of Thomas et al. [3]. We have made CSPA in the form of hybrid card, which can be mounted near the detector on the same mother board to reduce the capacitive noise of cables. The CSPAs are designed for charge sensitivity of 20 mV/MeV, this allow it to detect high energy charge particles without saturation.

Fig. 2 Rear view of detectors consisting all 15 CSPA (30 mm x 30 mm)

Performance of the detectors

The characteristics of the detector were investigated in offline tests with mixed source of ^{239}Pu (5.15 MeV) and ^{241}Am (5.48 MeV). A mask consisting a matrix of holes (1 mm diameter and 5 mm separation) was used to investigate the position resolution. The output signals from CSPAs were fed to Mesytec (STM-16+) shaping amplifiers via shielded twisted pair cable. We have used two different shaping amplifiers with 1 µs and 3 µs shaping time. 1 µs shaping time was used for position signal and 3 µs for energy signals. Information on positions and energy loss of particle in the detector were obtained by pulse height analysis. The pulse heights were digitized by a 12 bit CAMAC ADC (Philips 7186H). *X* and *Y* positions is determined using the following relations:

$$X = ((q_A + q_B) - (q_C + q_D))$$

$$Y = ((q_B + q_C) - (q_A + q_D))$$

Here q_A, q_B, q_C, and q_D are the normalized charge collected at the corners A, B, C, and D respectively. Charges collected at the four corners are normalized by energy signal (*E*) to disentangle the noise contributions from small amplitude signals due to interactions at the opposite corners. Fig. 3 shows the plot of position signal *X* and *Y* gated with energy signal.

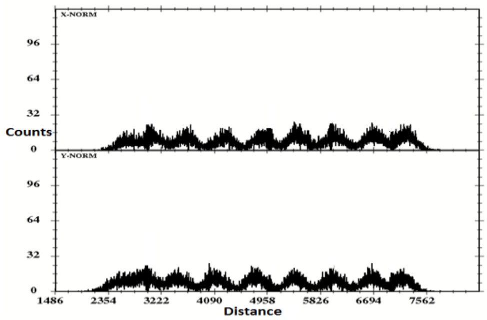

Fig. 3 X and Y position signals.

A 2D plot of (*X* versus *Y*) of detector is shown in Fig. 4. As we can see, non-linearity was enhanced at the edges due to the pincushion effect [2]. This is due to loss of smaller strength of the signal by shaping amplifier due to ballistic deficit [2]. The average non-linearity was found to be 4.8% (rms). The position resolution was found to be ~ 2.5 mm (FWHM). Fig. 5 shows the energy spectrum, two energy peaks of plutonium (5.15 MeV) and americium (5.48 MeV) are well resolved. Energy resolution was found to be 183 keV (FWHM) for 5.15 MeV and 200 keV (FWHM) for 5.48 MeV alpha particles.

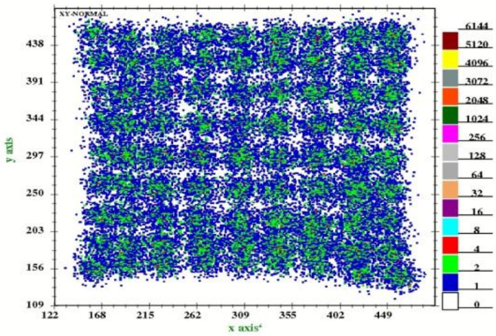

Fig. 4 2D (*X* vs. *Y*) plot, showing the matrix of holes.

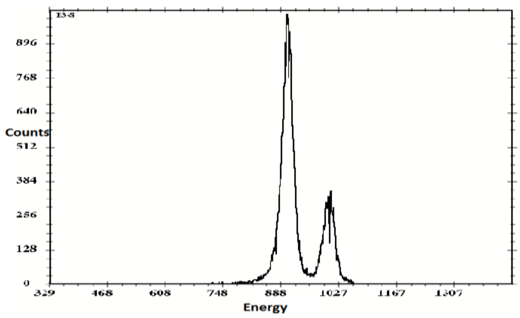

Fig. 5 Energy spectrum of mixed α-source (^{239}Pu and ^{241}Am).

Future perspective

In future, we plan to use shaping amplifier having shorter shaping time (0.5 µs) for position signal extraction. The nonlinearity will be reduced by adding series termination at all the corners. Nonlinearity will further reduce in software by developing a suitable algorithm [1].

References:

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