MICROPIXEL AVALANCHE PHOTODIODE AS ALPHA PARTICLE DETECTOR

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ABSTRACT

Public security (explosives and drugs detection) and environment protection (radioactive isotope contamination detection) issues require new methods for detection of ionizing radiation. The most challenging is registration of alpha particles that are absorbed basically at the surface of a detector. The goal of the work is an investigation of detection of alpha particles by silicon micro-pixel photo diodes (MAPD) in combination with lutetium fine silicate (LFS) scintillators.

Challenges of the last decade have made detection of explosives and drugs in baggage and large cargoes an important task. A tagged neutron method was developed to solve the first problem [2]. The method is based on the following principles. The creation of a neutron in the generator as a result of interaction of deuterium beam with a tritium target is accompanied by emission of alpha particle flying in the opposite to the neutron direction. Detection of the alpha particle allows one to determine direction of the neutron and generate a trigger signal. Capture of neutrons within a given nuclei produces a specific for the resulting isotope gamma spectrum. Analysis of the gamma spectrum allows one to determine atomic composition of the substance, and, therefore, identify it. Another issue is a detection of radioactive isotope contamination in various environments. The most challenging task here is registration of alpha particles what do not penetrate deeply within the detector volume.

Design and operation principles of the MAPD were described in [1]. Basic structure of the MAPD is shown in Fig. 1. Investigated photodiode MAPD-3N had 3x3 mm^2 active area and pixel density 1.5×10^4 mm^{-2}. A single pixel gain was of order 10^4 depending on bias. High pixel density provided for linearity of device's response in wide range of registered energies and sufficient energy resolution.

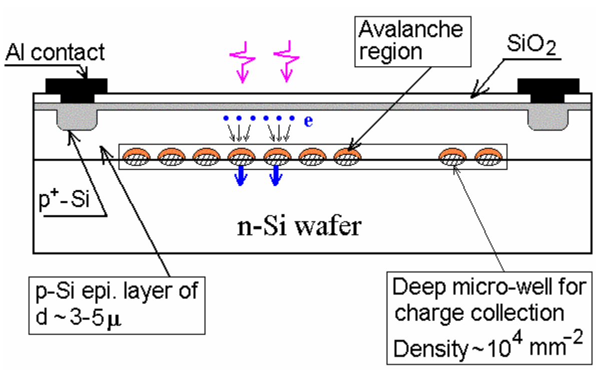

Fig. 1. Basic structure of the MAPD.

A ^{241}Am isotope (kinetic energy of alpha particles is 5.486 MeV (85 %) and 5.443 MeV (13 %), half life period is 432.7 years) was used as an alpha source. The lutetium fine silicate (LFS) crystal named as "LFS-8" was used as a scintillator. The size of LFS-8 was selected 3x3x0.5 mm^3. The decay time of LFS-8 was 19 ns. LFS-8 was coupled to the MAPD-3N with silicone optical grease. The MAPD samples and LFS-8 scintillators were manufactured in collaboration with Zecotek Photonics Singapore Pte. Ltd. [4].

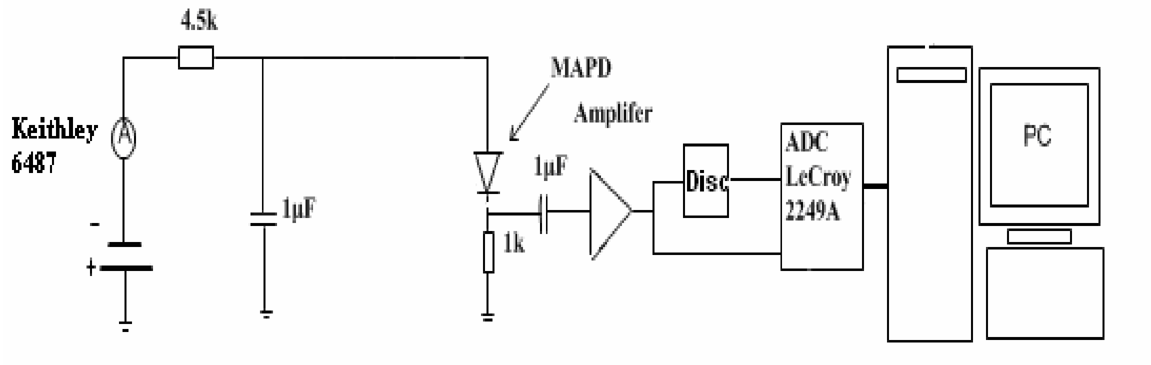

Fig. 2. Block diagram of the experimental setup.

Fig. 2 shows block diagram of the experimental setup. Keithley 6487 voltage source was connected to MAPD through RC-filter. The signals were read out from 1kΩ load resistor through the coupling capacitor and a linear amplifier. Gain of the amplifier was 20 in the case of measurement with LFS scintillator. Delayed signal was fed into LeCroy 2249W ADC. CAEN N-48 shaping discriminator was used to form a gate signal for the ADC. Digitized signal was read out by a personal computer through CAMAC interface. Peak positions and their full width at half maximum (FWHM) were obtained from Gaussian fit. All measurements were carried out at room temperature.

In order to measure alpha spectra with LFS-8 scintillator the later was placed on top of the MAPD under the ^{241}Am source. The scintillator crystal was not covered in order to avoid attenuation of alpha particle flux. When an alpha particle hits the scintillator it deposits its entire energy producing light pulse. The scintillation light was detected by MAPD.

Fig. 3 shows the alpha spectrum measured with the LFS-8 scintillator and MAPD at bias voltages in a range of 92.3-93.5V. The measured energy resolution for the 5.5 MeV alpha particles was 14.6% at 93.2V. The quite low energy resolution can be explained by three reasons. First, part of the scintillation light has escaped uncovered LFS-8 scintillator because in our case the reflecting cover would absorb the alpha particles. Second, because of very thin scintillator (0.5 mm) the scintillation photons produced by the alpha particle hit a small part of the detector surface with limited number of pixels. Finally, because of the finite number of the MAPD pixels many photons could hit the same pixel producing the same resulting signal as in the case when only one photon would hit the pixel.

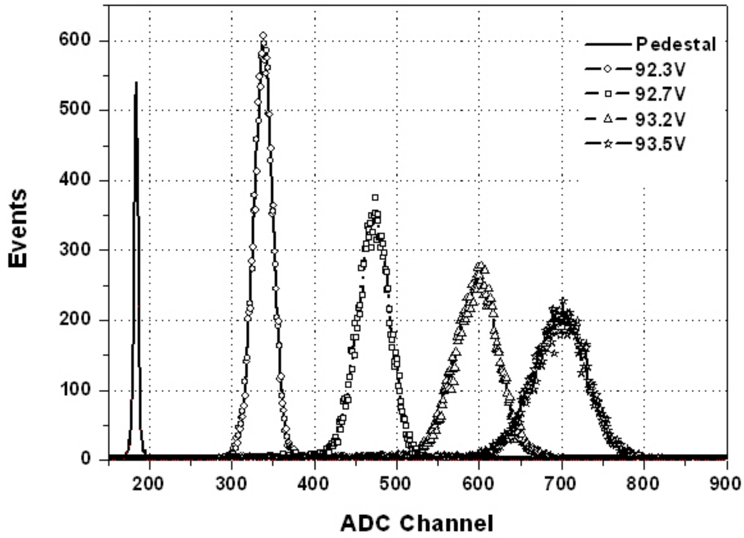

Fig. 3. Spectra of the alpha particle measured with LFS scintillator and MAPD at the different bias voltages (amplifier gain is 20).

The obtained results show that the MAPD could be used to detect and count alpha particles by itself as well as in combination with scintillators.

The measured energy resolution for the 5.5 MeV alpha particles in this case is sufficient to separate signal from background for most practical purposes although additional studies are required to improve energy resolution for alpha particles.

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